ARTICLE
Escape from traditional learning: A neuroscience escape room activity for neuroscience education

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This paper provides a step-by-step guide to developing a neuroscience themed escape room. We designed the escape room based on our introductory neuroscience learning outcomes which required students to remember key concepts while working together both as a group and individually to solve six neuroscience-themed challenges. Data include time to escape, as well as the results of a post-event survey that had individual students rate the value of the activity, their own personal effort, and their perceptions of instructor contribution. We found that students enjoyed this activity and that the amount of personal effort put in by the student was correlated with how fast they solved the six challenges in our escape room. We conclude that the escape room is a low cost, high impact event that can motivate student learning of neuroscience and promote retention.

Key words: educational escape room, interactive learning, neuroscience, game-based learning

A frantic voice cries out, “Where is the frontal lobe?” A voice answers, “I don't know, but which cranial nerves control the eyes?” “$(LR_6S0_4)_3$,” says a third voice, “Does CFS flow from the lateral ventricle or the interventricular foramen first?” The gamemaster asks, “Are you asking for a hint?” This is not a conversation you might hear in a neuroscience lab, but one that happened within our neuroscience-themed escape room.

Developing critical and integrative thinking skills and learning how to communicate scientific information are two of the hallmarks of a well-designed neuroscience curriculum (Ramirez et al., 2020; Wiertelak & Ramirez, 2008). In addition, numerous studies have shown that lectures supplemented with educational student experiences is an effective way to deliver course material (Kober, 2015). To that end, we developed a neuroscience-themed escape room, designed with specific learning outcomes in mind from our introductory neuroscience class.

Since the first documented instance of an escape room in Japan in 2007, escape rooms have become a popular entertainment activity across the globe (Nicholson, 2015). It should not be surprising then, that educators have adapted the escape room for use in the classroom (Sanchez & Plumettaz-Sieber, 2019). The appeal of using escape rooms as an education tool comes from the proposed myriad of benefits to students who participate in them, including the opportunity to engage in teamwork, to apply knowledge from the classroom to a “real world” scenario, and to develop cognitive skills such as problem solving and critical thinking. Indeed, in a systematic review of the literature, Taraldesen et al. (2020) noted a rise in the popularity of studying escape rooms as didactic tools. After reviewing the literature, Veldkamp et al. (2020) proposed five recommendations for those interested in creating escape rooms for educational purposes, including the importance of aligning learning goals with the escape room content.

In a systematic review of escape rooms in STEM education, Lathwesen and Belova (2021), found numerous papers on the subject starting around the year 2016. In the 93 articles that met their search criteria, the majority were centered around medical education (especially in the field of nursing), often with the goal to solidify the learning of routine medical procedures. The next most popular themes were from the fields of chemistry (15) and computer science (14). While the authors categorized 4 papers as biology-themed and 5 as general science, none of these papers used neuroscience-themed concepts.

In a review of the literature, we were only able to identify two articles concerning neuroscience-themed concepts. Lim (2023) reported on a physical escape room where 3-4 participants had to find an antidote for a neurotoxin. Their main objective was to help develop soft skills (collaboration, critical thinking) within a neuroscience-themed escape room. Nakashyan and Clabough (2023) reported on an escape room that had both physical and online components where participants were sleep lab workers who had to find out which of their patients planted a device called Chemical X that would prevent anyone from sleeping ever again. This escape room was tested in a large introductory sleep course and thus is scalable for large numbers of participants. The specific puzzles were informed by the course’s sleep learning objectives. The participants in both studies found the escape room entertaining and reported increases in soft skills development. The Nakashyan and Clabough (2023) also reported that participants reported a more solid understanding of the neuroscience concepts presented in the escape room.

Our motivation here is to present a step-by-step guide for producing a neuroscience-themed escape room. Our escape room included six neuroscience-themed challenges based on our learning outcomes for introductory neuroscience classes. Our escape room was modeled after commercial escape rooms and so was conducted entirely within a physical space with no online challenges. We measured the time to escape and had students fill out the ASPECT survey after completion (Wiggins et al., 2017). This survey measured the students' perceptions of engagement while participating in the escape room.

MATERIALS AND METHODS

Description of Neuroscience Escape Room Activity

The event was sponsored by the NSU's Office of Student Success & Pre-Health Services. All pre-health students were invited to attend regardless of major. On the registration site, it was recommended that students had previously completed either Introduction to Neuroscience and/or Introduction to Neuroanatomy. We did not offer course credit, but this could be offered as either extra credit or a low-stake assignment in the future. Student participants self-selected into groups of 4 and had 30 minutes to complete 6 challenges in the Neuroscience Escape Room. Only one team at a time engaged in the escape room. We ran the escape room over several days as our schedule permitted. We opted to cap the number of students per group at 4 based on the physical size of our conference room and our learning objectives, but groups could be as high as 6. Group size should be small enough so that all members must contribute to the outcome and to avoid social loafing.

We set up the challenges around a long table in our conference room (Figure 1). The gamemaster (JM, one of the authors of this paper) is a neuroscience professor and was present throughout the entire exercise. The gamemaster read and enforced the rules and was available to give out hints if a team was stuck. The rules were standard escape room rules: student teams had to work together to solve all 6 challenges within our 30-minute time frame. The challenges could be completed in any order and by any member of the team. If students got stuck, they could ask for a hint from the gamemaster. Students were told that each hint would cost them a 1-minute time deduction. Each challenge, when solved, opened a lock on a large chest located at the front of the room. The challenges either revealed a key or a combination. When all challenges were solved, all locks were opened, and the game ended.

The following general instructions were given to each team by the gamemaster at the start of each session:

Welcome to the Neuroscience Escape Room! Congratulations, I've reached my threshold and you done got on my last nerve! Figuratively. I've accidentally infected you with tetrodotoxin at a dose likely to have rapid onset. Sorry, I'm not so good at lab math. My bad. Unfortunately, there is no antidote for tetrodotoxin toxicity. However, you can still go out a winner. Or a loser. To complete this escape room, you'll have to propagate from node to node and release the contents from the synaptic bulb before time runs out. This is an all-or-none event. Your team will have 30 minutes to escape the room. There are 6 challenges in the room which will reveal the combination of the locks on the main chamber. You may work together, separately, and in any order. A maximum of 3 hints are available with a 1-minute penalty per hint. Some ground rules: No moving any equipment. No forcing the locked box or padlocks open. Be gentle with the locks and the locked box. No cell phone use is permitted. However, use of the computer is permitted. Please keep the integrity of the game. Do not discuss the challenges with other people until all participants have completed the escape room and the event is over on November 1st. The game ends when you successfully unlock the main chamber or the timer runs out. You may begin. Good luck!

Teams were timed starting from when they entered the room until they solved the last challenge. No teams used the computer in the room, but one team did ask for hints from the gamemaster. Teams that completed all challenges were ranked according to their time. At the end of the escape room, student participants received a gift bag and snacks for participating and were told that there would be cash prizes for the top 3 teams. Each individual in the first, second, and third place teams received a $100, $25, or $10 gift card respectively. Prizes were generously donated by NSU's College of Psychology and the NSU Office of Student Success.

All materials, pictures, and data from the escape room can be found at https://osf.io/nd8hc/. Materials and pictures can be found in a supplement (supplementary material 1) to this manuscript.

Description of the neuroscience escape room challenges

We developed 6 challenges that mapped on to learning outcomes from our NEUR 2500: Introduction to Neuroscience class. In addition to the individual challenge resources detailed below, we also used one large treasure box that was locked with 6 locks. One lock required a key while the other required a 3-, 4-, or 5-digit code.

Figure 1. A picture of the conference room where the escape room took place.

Challenge 1: Brain Puzzle (Figure 2A)
Resources needed: Brain lobe puzzle. We purchased a wooden one online, but it could be made with paper or foam.
Challenge instructions: Students needed to find the 5 lobe puzzle pieces that were hidden around the room. The pieces themselves had numbers on them which corresponded to a combination lock. The order of the numbers for the lock was indicated on the bottom side of the puzzle.
Learning outcome: Identify and describe the functions of the lobes of the cerebral hemispheres.

Challenge 2: Ventricular System (Figure 2B)
Resources needed: ventricular model (optional), 25 plastic test tubes, ~50 white and ~50 blue puff balls, index cards
Challenge instructions: Students needed to place the 5 cards in the correct order of CSF flow through each ventricle. Index cards were titled 1) lateral ventricle, 2) interventricular foramen, 3) third ventricle, 4) mesencephalic aqueduct, and 5) fourth ventricle. Each card gave instructions on how to place 5 white or blue puff balls into one of 5 plastic test tubes. When put together correctly, the 5 colored puff balls in the plastic test tubes revealed a number. The order of the numbers for the lock was revealed by the flow of CSF through the ventricular system.
Learning outcome: Identify the components of the ventricular system and describe the flow of CSF through the ventricles.

Challenge 3: Crossword puzzle challenge (Figure 2C)
Resources needed: We used Scrabble tiles, but any letter tiles would work
Challenge instructions: Students had to solve a crossword puzzle with 4 clues (2 vertical; 2 horizontal) about the structure and function of the nervous system. The sum of the numbers on the tiles for each word revealed a digit for one of the combination locks. The order of the digits for the lock was revealed by the order of the words on the crossword (e.g., #1 down = 1st number, #2 down = 2nd number. #3 across = 3rd number, #4 across = 4th number).
Learning outcome: Explain the structure and function of the nervous system at various levels of organization.

Challenge 4: Action Potential (Figure 2D)
Resources needed: 5 hardback canvases
Challenge instructions: Students had to put, in order that they happen during an action potential, pictures describing the flow of ions across a membrane. The order of the numbers for the lock was revealed by the order of pictures.
Learning outcome: Describe how movement of ions across the neuron membrane leads to an action potential.

Challenge 5: Cranial Nerves (Figure 2E)
Resources needed: We used 3 shark plushies, as our school mascot is a shark. One shark was blindfolded, one had earmuffs, and one had a mouth gag.
Challenge instructions: Students had to identify the cranial nerve associated with vision (CN2), audition (CN8), and speech (CN7; as multiple cranial nerves are associated with speech, a note next to this shark read "Think Facial"). The order of the cranial nerves indicated the order of the combination lock, see no evil, hear no evil, speak no evil, which was the order of the shark plushies on the table.
Learning outcome: Identify the cranial nerves and their function.

Challenge 6: DaVinci Neuron (Figure 2F)
Resources needed: A cryptex security box, shark plushie containing a plastic neuron hidden inside the shark's mouth, and a sign that read "One neuron short of a synapse."
Challenge instructions: Students had to figure out which 6-letter word opened the cryptex (NEURON). When opened, the cryptex revealed a hidden key.
Learning outcome: Evaluate functional neuroanatomy at the gross, cellular, and subcellular levels.

After each group completed the challenges, the gamemaster walked through each station to briefly review concepts presented in each station and explained how the challenge related to a learning objective.

Participant Survey
Following the escape room, participants were asked if they would like to participate in a survey about their experience with the Escape Room. After giving informed consent,

Figure 2. Pictures of each of the neuroscience challenges. A. Brain puzzle, B. Ventricular system challenge, C. Crossword puzzle, D. Action potential challenge, E. Cranial nerve challenge, F. DaVinci Neuron.

participants answered some demographic questions and then filled out the ASPECT survey to assess participant experience (Wiggins et al., 2017). This survey provides a rapid, easily administered means to measure student perception of engagement in an active-learning classroom. There are 3 subscales which independently measure 1) the value of this activity; 2) the personal effort students expend on this activity, and 3) perceptions of instructor contribution. This study was approved by the NSU Institutional Review Board.

RESULTS

There were 11 teams that participated in the escape room. While participants completed the escape room activities as a group, each participant was asked to fill out the survey themselves. Forty participants filled out the survey (9 male, 31 female). The average (standard deviation) age of participants was 20.0 +-1.16 and the average (standard deviation) number of semesters completed at NSU was 5 +-2. Eighty percent of participants indicated they were majoring in neuroscience (32.5%), biology (27.5%), or were neuroscience and biology double majors (20%). The remaining majors included psychology (7.5%), public health (5%), exercise and sports science (2.5%), pre-nursing (2.5%), and speech-language and communication disorders (2.5%). We also asked whether participants had taken any of the following classes: NEUR 2500: Introduction to Neuroscience (58%), NEUR 2600: Introduction to Neuroanatomy (53%), PSYC 2100: Biological Basis of Behavior (15%), BIOL 3320: Anatomy and Physiology 1 (33%), or BIOL 3330: Anatomy and Physiology 2 (23%). All teams that completed the escape room had at least one participant that had completed our Introduction to Neuroscience course or Introduction to Neuroanatomy course. Finally, we asked participants if they had any other comments to share.

Of the 11 teams, there were 3 teams that did not complete the challenges in time. The fastest team completed the challenges in 14 minutes and 26 seconds; the slowest team completed the challenges in 32 min and 15 sec (this team asked for 3 hints and so had an added 3-minute time deduction added to their time). The average completion time was 24.32 min. Univariate ANOVAs revealed no significant differences in completion time based on major or whether any of the above-mentioned classes were taken by the participant (all *p*s > .05).

We next calculated the three subscales from the ASPECT survey for each participant and normalized each score to be between 1-100%. We did this because two questions that contributed to the *value* subscale were optional, and all three subscales were on different scales. We report here the analyses done on the normalized scores, but the results did not change when we ran the same analyses on the raw data. Figure 3 displays the results for the three subscales, including the *value* of this activity, the *personal effort* students expend on this activity, and perceptions of *instructor contribution*. Table 1 displays the correlations between all three subscales and time

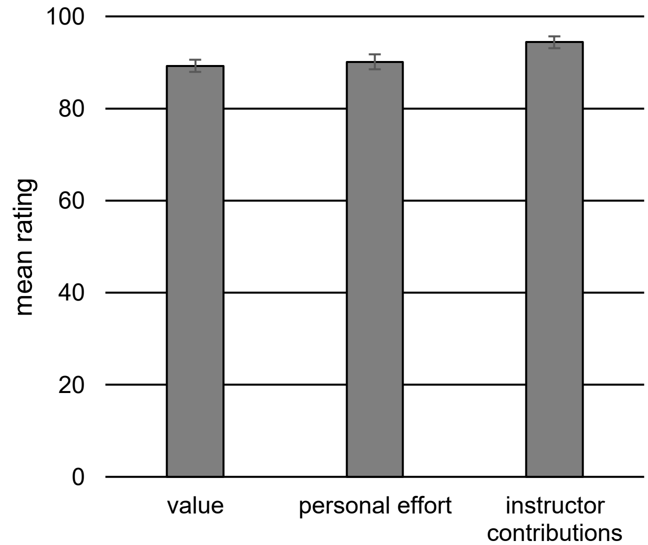

Figure 3. Mean normalized ratings for the ASPECT survey subscales of the escape room's value to the participant, the amount of personal effort they extended, and their perceptions of the instructor's contributions. Error bars are standard errors of the mean.

	completion time	value	personal effort	instructor contribution
completion time	1	-0.185	-.373*	-0.033
value		1	.667**	.542**
personal effort			1	.368*
instructor contribution				1

Table 1. Correlations between the completion time from the escape room and the three subscales of the ASPECT survey. * $p < .05$; ** $p < .01$.

completion. While all 3 subscales were high and were correlated with one another, only personal effort was significantly correlated with the completion time (r(29) = -.37; p=.04); those who put in the most effort, finished sooner.

DISCUSSION

The majority of teams completed the escape room within the allotted 30 minutes. We chose this time frame for both practical and pedagogical reasons. First, we conducted the escape room outside of class time. To accommodate the large number of students, and our faculty member's time, we limited the time to complete to 30 minutes. Second, we wanted students to practice their teamwork skills. When time is limited, people need to work together as a team to accomplish their goal. Third, like most neuroscience majors (Ramos et al., 2016), many of our students are planning on attending medical school. Learning to work under time pressure is a soft skill that any future healthcare professional will need to master.

The post-escape room survey revealed high subscales indicating that students found the escape room valuable to their learning, that they put forth a large amount of personal effort, and that they perceived the instructor's contribution to their learning as high. The fact that students perceived the instructor contribution as high is important because a student's belief about how involved a faculty is in their learning increases student motivation and achievement, especially for students in underrepresented minority groups (Canning et al., 2019; Ramirez, 2020). In addition, students who believe that an educational exercise is valuable are more motivated to learn (Harefa et al., 2023). Both beliefs were positively correlated with the amount of effort that students put into the escape room. Interestingly, although students found the activity highly valuable and believed their instructor put in a lot of effort, only student personal effort was significantly correlated with the time needed to escape the room; not surprisingly, students who put in a lot of effort finished the escape room faster. This result fits within the body of research that shows that a student's personal effort, above and beyond any other factor, best predicts student achievement (Pace, 1982; Sun et al., 2022), with the caveat that "effort" should be defined as something beyond time spent studying (Dunlosky et al., 2020). While we did not specifically measure knowledge gains, future research should investigate how the ASPECT survey subscales correlate with student learning in general, and what specific aspects of personal effort are being captured by the survey.

One limitation of our study was that we did not test directly student understanding of the concepts covered in the escape room as could be done with a knowledge pre-post-test. We did, however, conduct a debriefing after the event to review key concepts covered in the escape room. Debriefing allows students to further solidify knowledge gained while involved in the activity (Sanchez & Plumettaz-Sieber, 2019). Future instances of an escape room should explicitly include a low stakes (or even no stakes) knowledge test to assess student learning.

Finally, as academia approaches the "enrollment cliff" with decreasing numbers of students enrolling at colleges, departments are being tasked with helping to recruit students to their majors. We asked students to add any comments they wanted to about the escape room. Of the thirteen responses, the words "love" and/or "fun" appeared in almost every comment, indicating an extremely positive experience for students. Escape rooms have been used successfully as a recruitment event for nursing students (Connelley et al., 2018). It may be possible escape rooms can be used as a recruitment tool for departments that house the neuroscience major. But only if we can find the frontal lobe!

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