Benefits of an Escape Room as a Novel Educational Activity for Radiology Residents

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Rationale and Objectives: We created a radiology Escape Room, a competitive game where a team of players must discover clues and solve a mystery to escape a "locked" room. To succeed, players must collaborate and think critically and creatively. Our objectives were to provide a novel team-building activity, teach interesting content about radiology as a specialty, cultivate grit, and share the game with other programs.

Materials and Methods: Escape Rooms were held during orientation (BOOT Camp) for incoming radiology residents and for upper level residents and faculty with advanced content (four teams totaling 20 residents and faculty). We repeated the Escape Room 27 times for 144 residents from more than 10 countries at Radiological Society of North America (RSNA) 2018.

Results: Players were engaged and competitive. They were able to connect the activity to their future responsibilities – analyzing knowledge under pressure (being on call), communicating effectively (conveying results and recommendations), having the dexterity and motor skills required for physical puzzles (hand-on procedures), being able to multi-task and come up with differential diagnoses under extreme stress and time pressure (being on call). A post-RSNA survey confirmed satisfaction with the activity, with overall enjoyment receiving the highest rating.

Conclusion: It is feasible to create a portable, inexpensive Escape Room as a novel educational platform for radiology residents. Combining knowledge-based challenges and technical skills in a live-action game simulated a real-life situation in which vital patient information must be collected and reported concisely and accurately. A Game Guide is available to program directors and medical educators upon request.

Keywords: Educational games; Escape room; gamification; millennials; radiology; residents.

INTRODUCTION

The transition from intern to radiology resident is stressful and surprisingly challenging. New responsibilities require learning a high volume of complex information while simultaneously adapting to a new peer group in a new work environment. We reported previously that including team-building activities during our BOOT Camp orientation fostered the development of camaraderie and support new residents need to meet these challenges (1). Millennial residents crave active engagement, both in and out of the reading room, and prefer multimedia learning. They are motivated by achievement and affiliation. They expect their educational experiences to include explicit goal-setting, relevance, continuous feedback, transparency, and autonomy (2). We envisioned a radiology-themed Escape Room game as an innovative approach to meeting these generational preferences.

Newer teaching methods, especially the flipped classroom, audience response technology, team-based learning, long-distance teaching, and active/experiential learning, are recommended to complement the traditional lecture (3). Likewise, board and card games have been developed for teaching medical concepts and specific clinical skills (4–6). Playing a game creates a dynamic educational environment that enhances retention of knowledge and reinforces learning (7). "Gamification", defined as the use of game design elements in a nongame context, has become a popular instructional method in K-12 and higher education (8–10). Although gamification has been shown to make a positive impact on the teaching/learning process, medical education is in the early stages of embracing it as a teaching method (7,11–14). Well-designed games based on sound adult learning theory model the ancient Chinese proverb, "Tell me and I forget, teach me and I may remember, involve me and I learn."

Acad Radiol 2020; 27:276–283

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https://doi.org/10.1016/j.acra.2019.04.021

A newer type of gamification with potential educational benefits is the Escape Room. An Escape Room is a competitive physical adventure game within a prescribed setting, constrained by rules and procedures, where a team of players must discover clues and solve a mystery to escape a "locked" room. They are physical versions of "escape the room" video games, set in fictional locations. Currently, they are becoming popular as team building exercises. Escape Room experiences require players to think critically and creatively, making them a good fit for millennial residents who crave active engagement. Learning results from the experience of playing the game, not the academic content (11).

When we initiated our project, there was no literature on the use of Escape Rooms in medical education. Furthermore, our collective experience was limited to commercial recreational experiences. We aimed to create a radiology themed Escape Room game as a novel activity for radiology residents. Our objectives were to provide a unique team building activity targeted to radiology residents, teach interesting content about radiology as a medical specialty, cultivate grit, and share the resource with any program in the country that was interested in replicating the activity for their residents (Fig 1).

It has been suggested that playing an Escape room may cultivate grit, which research has shown can be a better predictor of success than standardized tests and has also been associated with decreased burnout and increased psychological well-being among residents. Defined as "perseverance and passion for long-term goals," Duckworth found through her research that grit was an independent predictor of achievement (15).

Figure 1. Promotional poster for radiology Escape Room featuring Marie Curie.

Small studies of grit among surgical residents demonstrated grit was predictive of psychological health and suggested that it is learnable and teachable (16). Resilience is an aspect of grit important in medical school, residency, and as a physician. In the face of failure, disappointment or even boredom, the gritty individual stays the course.

MATERIALS AND METHODS

We applied for and received the 2018 Jerome Arndt grant from the Association of Program Directors in Radiology (APDR), an award intended to encourage development of resources for the membership, including innovative projects in radiology education. This funding allowed us to retain the services of Wero Creative, a Toronto-based game studio, for their expertise in design, including theme, puzzles, and set up instructions.

We built our Escape Room on fundamental adult learning principles. Residents are autonomous, self-directed, and goal-oriented. They are motivated by the need to know and their readiness and desire to learn. Learning that is based on their life experiences and is relevant to their work environment is most highly valued (17). We designed our room and its challenges around interesting radiology knowledge and technical skills.

We created four branches of puzzles which, when successfully completed, win the game. Mental puzzles require players to use critical thinking skills and logic to decipher clues (knowledge). Physical puzzles require the manipulation of objects to overcome a challenge to get the reward (technical skills). Each puzzle uses a simple game loop: a challenge (e.g., a locked box), a solution (e.g., the combination), and a reward (e.g., something inside the box). Every challenge creates a learning experience. Puzzles combine information the player should know (input) with information the player should have acquired by the end of the experience (output). There is no set order in which the puzzles must be finished but all must be completed to reveal the final clue, a meta-puzzle with the final challenge derived from the previous solutions (Fig 2).

Examples of educational material and radiology knowledge tested in this escape room included matching or naming classic imaging diagnoses based on written description and testable buzzwords, identification of classic imaging diagnoses within the chest on computed tomography or characteristic intra-abdominal pathology. Additionally, identification of neuroanatomy via CT/MRI, identification of bone tumors, soft tissue masses, fractures types, and eponyms was tested. There were also questions about muscle insertion and origin anatomy, tendon and ligament anatomy, and bones or osseous structures which utilized the full sized anatomic skeleton prop. Imaging diagnosis questions could be shown on any modality including radiography, CT, MRI, nuclear medicine scintigraphy.

Knowledge about radiotracers used in nuclear medicine and their production, or radiation safety dose limits and the detrimental effects of radiation exposure, or proper handling

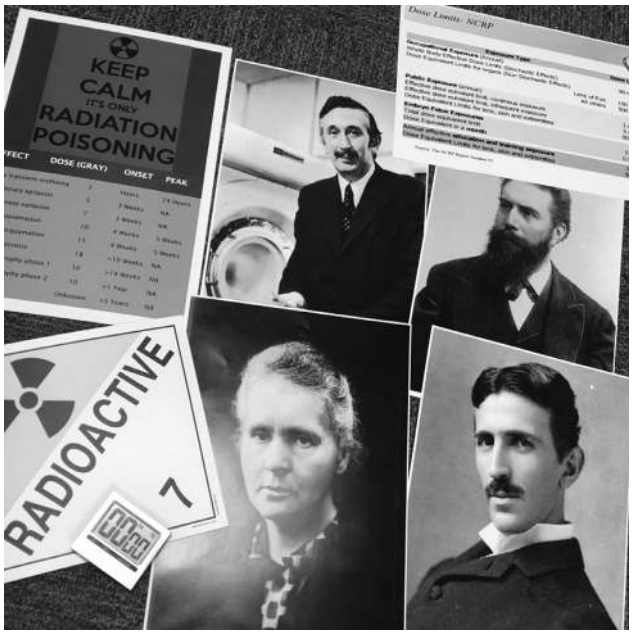

Figure 2. Various game and clue materials.

and detection of radiative materials and use measuring devices could also be asked. For example, you could show a Tc-99m bone scan with classic findings or Paget's disease and ask the players to name the keV of the radiotracer use in this study or the classic botanical sign associated with Paget's disease. Furthermore, demonstration of proper ultrasound scanning technique and use of associated equipment could be required. For example, you could have the players scan a synthetic material with a hidden code to emphasize scanning technique and dexterity.

We used a single small-to-medium sized room that could be darkened like a reading room, was relatively quiet to optimize team discussions, and was lockable to secure the props and setup. A portable ultrasound machine and an old-fashioned light box were procured. The game master distributed props throughout the room and ensured there were not too many extraneous objects that could confuse players. Mock-trials with volunteer faculty and senior residents tested the feasibility of prop and equipment placement, light sources, and hiding places. Trial runs revealed that some boxes had faulty latches and could be broken into without solving the code for the padlock and some boxes were able to be pried slightly open so the secret card could fall out. A few players were able to guess the final pass phrase without solving all the puzzles. Certain puzzles were too long or difficult and could cause a bottleneck. Extra clues and modifications were made as suggested. Placement of props, puzzles, and equipment varied depending on the room available and electrical outlet locations. Extra props, such as buckets with radioactive stickers, provided extra hiding space for one of our paper-based puzzles. Depending on the light source available, we provided various sized lanterns or a small spotlight. If maltreated, fragile homemade props can fail to allow accurate deciphering; however, extra clues can be placed in the room to allow them to complete the decipher if needed.

Players were scheduled in teams of 4 to 6. They were not required to bring any tools or materials to the game; there were no predetermined roles or tasks. They were, however, expected to maintain the confidentiality of the room's contents and puzzles and not postcritical content to any social media sites.

Once the team assembled, the game master (either the Program Director or the senior resident who designed the room) explained the challenge and the rules. Our rules were (1) No running, climbing, jumping or standing on furniture; everything needed is at working height. (2) No internet use; everything needed to solve the puzzles is in the room. (3) No pictures; it ruins the surprise for others. (4) No force needed; only two-fingers of strength is required to open objects. (5) Be delicate with props, padlocks, etc. No ripping, tearing, or destroying; if unsure, ask the game master. (6) Players are responsible for their own safety. (7) You can exit at any time if you need to, but if you leave before completing the game the game will be over for you. (8) Ignore wiring, electrical outlets, thermostat, and light switches. (9) Talk and listen to each other, and work as a team.

At the appointed time, the game master introduced players to the scenario. *A doctor who failed to respect the sophisticated technology used in radiology subsequently irradiated himself, became progressively irrational and delusional, and disappeared years ago, living now beneath this very building, plotting his revenge. He demands the players complete his series of tests or he will atomize the entire building*! The game master exited the room. The door closed. The clock began counting down. The team had 1 hour to "escape the room" The room was "locked" in name only; players could exit at any time but not return.

The game master observed team behaviors and monitored the team's progress by video chatting via Facetime or Skype. The game master's role was to make sure players had a fair experience, the physical puzzles worked as planned and the players did not damage the room or need emergency assistance. When players failed to progress, they could request up to three clues. The game master intervened only when needed to avoid players becoming overly frustrated. When players called the game master with the correct pass-phrase within the allotted time, they escaped. Players failed to escape if they ran out of time.

Because social interaction is vital to the learning process and immediate feedback after a game enhances the learning experience, the game master debriefed teams immediately after each session. This helped players learn from each other and relate the activity to the reality of their future lives (18). The discussion focused on what was done, how well it worked from the player's perspective, and how the lessons learned could be applied (Figs 3 and 4).

Using items from the medical education literature, we created an 18-item postevent survey. We adapted pre-existing survey instruments to assess resident satisfaction, motivation, learning, and skills. We used items reported by Kinio and colleagues to assess motivation, satisfaction, and engagement (6). We added items from Meterissian and colleague's questionnaire to assess their interactive games-based approach to learning (13). Finally, we included selected items from Zhang and colleague's

Figure 3. UAMS escape room door design. UAMS, University of Arkansas for Medical Sciences.

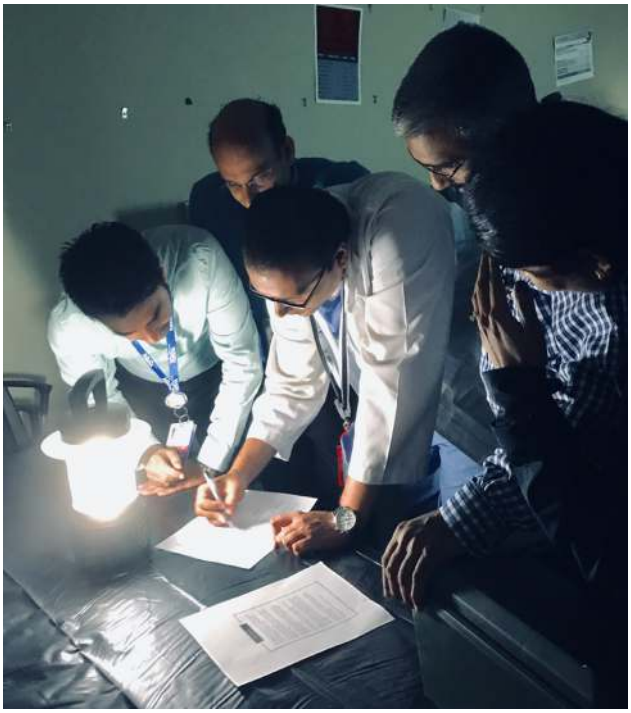

Figure 4. UAMS students and faculty during first trial run at UAMS. UAMS, University of Arkansas for Medical Sciences. (Color version of figure is available online.)

postparticipation in a commercial Escape Room survey that focused on feelings, experiences, and problem-solving techniques (19). An additional five open response items were included to obtain feedback for improvement. Our Institutional Review Board determined this survey protocol met exemption criteria.

We used the previously validated 12-point Grit Scale as a measure of perseverance. The scale does not contain sensitive items which residents might be reluctant to answer and it only takes a few minutes to administer. The maximum score on this scale is 5 (extremely gritty), and the lowest score is 1 (not at all gritty (15)).

We were invited by the Radiological Society of North America (RSNA) to offer the Escape Room to residents attending the 2018 annual meeting in Chicago (Figs 5 and 6). This gave us access to large and very diverse group of residents to assess the perceived benefits the Escape Room activity (Fig 7). The Senior Manager for Survey Research and Program Evaluation at RSNA agreed to administer the postevent survey to all players. Invitations to participate in the survey were sent via email and responses were recorded anonymously, securely, and without personal identifiable data using Survey Monkey's Anonymous Responses survey option. The survey was open from December 5 until January 23 and three reminders were sent.

Finally, we produced a Game Guide for Program Directors including the puzzles, props (everything needed to run the game), flow (visual layout of puzzles and how they connect), layout (puzzle placement in the physical space), and notes (game rules, story script, tips for implementation). It is available to program directors and medical educators upon request.

RESULTS

BOOT Camp Results

A total of four Escape Room sessions were held during orientation (BOOT Camp), two for incoming radiology residents and two with advanced content for upper level residents and faculty (four teams totaling 20 residents and faculty). Players were engaged and the competition evoked friendly rivalry. As a learning platform, the game was fun and the players

Figure 5. Portion of interior escape room design and set-up at RSNA 2018. RSNA, Radiological Society of North America. (Color version of figure is available online.)

Figure 6. Co-creators Dr. Kedar Jambhekar and Dr. Rachel Pahls in front of escape room at RSNA 2018. RSNA, Radiological Society of North America. (Color version of figure is available online.)

Figure 7. Team of players from Germany at after playing escape room at RSNA 2018. RSNA, Radiological Society of North America. (Color version of figure is available online.)

unanimously reported that it "exceeded their expectations." Residents valued working in teams and interacting with faculty. Residents rated the quality and value of the game equally at 4.8 (1-5 scale). Residents demonstrated significant increase in grit from 3.7 to 4.1 (1-5 scale).

Knowledge-based challenges conveyed interesting content about radiology as a medical specialty. Radiology information needed to solve search-and-find clues, riddles, code-breaking puzzles, and ultimately a communication challenge simulated a real-life situation in which vital patient information must be collected and reported concisely and accurately. Game masters were able to observe players' knowledge gaps and interpersonal and communication skills under pressure.

The educational value of the Escape Room experience came not from the game itself, but as stimulation for a rich reflective process. By describing, analyzing, and communicating what they just experienced, players were able to link the activity to their future practice – analyzing radiology knowledge under pressure with limited time (being on call), communicating effectively (conveying results and recommendations), having the dexterity and motor skills required for some puzzles (hand-on procedures), being able to multi-task and come up with differential diagnoses under extreme stress and time pressure (being on call). Reflecting on their performance gave players an opportunity to assess their individual strengths and weaknesses (i.e., practice-based learning and improvement).

RSNA Results

We ran the Escape Room 27 times for 144 residents from more than 10 countries. This was a first Escape Room experience for almost half of the players (45%). All teams escaped. The shortest time to escape was 27 minutes 38 seconds and the longest was 58 minutes 9 seconds. More males (64%) than females (36%) participated. All players were millennials, born between 1982 and 2000. Residents who reported their current level of training were 11% R1, 28% R2, 17% R3, and 43% R4. Residents who reported the geographic location of their residency program represented the Pacific (4%), Central (27%), Northeast (12%), and Southeast (8%) regions, while 49% were from outside the United States.

The overall response rate for the postevent survey was 38.9% (56 of 144) (See Table 1). Satisfaction with the experience was high, with "overall enjoyment" receiving the highest rating (4.85 of 5). Players did not find the format to be stressful, nor would they prefer a didactic lecture to the interactive game. In terms of motivation, they found the challenges interesting and the activity moderately increased their interest in radiology. The similarity between the debriefing and checking-out with staff at the end of a shift was less discernible.

We found the Escape Room provided opportunities to teach and assess critical aspects of all six general competencies (See Table 2). Players agreed the Escape Room encouraged the use of collaboration, communication, and leadership skills, all critical to general competency development. Regarding learning, players agreed it promoted retention of information and identification of knowledge gaps. Players were neutral regarding a sparked interest to read more about radiology and the parallel between information needed to solve puzzles and information needed to work in the radiology department.

TABLE 1. Postevent Survey Results Response Rate 38.9% (Rating Scale, 1 Lowest to 5 Highest)

	(*n* = 56)
Satisfaction	
1. Overall, I enjoyed the escape room activity.	4.85
2. This format was stressful.	2.15
3. I found this game fun to play.	4.67
4. I felt like I was immersed in radiology.	3.98
5. I prefer didactic lectures to the game.	1.98
Motivation	
6. This activity increased my interest in radiology.	3.85
7. The challenges in the game were interesting to me.	4.52
8. The debriefing conducted by the game master at the end of the game was similar to checking -out with my staff at the end of a shift.	2.96
Learning	
9. The escape room activity increased my general knowledge in radiology.	3.52
10. This format helped me retain radiology information.	3.77
11. This format helped me identify knowledge gaps.	3.88
12. The information I needed to solve puzzles was similar to information I need to work in the radiology department.	3.42
13. This activity sparked my interest to read more about radiology.	3.94
Competencies	
14. The escape room encouraged the use of communication skills.	4.67
15. This activity encouraged the use of collaboration skills.	4.76
16. This activity encouraged the use of leadership skills.	4.59
Quality & Value as a Learning Platform?	
17. Quality	4.72
18. Value	4.48

When asked what they liked the most about the Escape Room, players mentioned the puzzles (41%), working as a team (35%), and the fun/novelty aspects (9%). Comments described the puzzles as "very interesting to solve," "challenging," "tough but interesting, "very interactive and fun," and "a great variety." Responses that endorsed team building included "creative way to interact with other residents and problem solve," "a completely unique team-building experience," "the chance to collaborate and work as a team," and "working together to solve a novel problem."

Suggestions for improvement included awarding prizes to the fastest teams, more imaging prompts (printed pictures of different modalities), better distinction of which objects can be manipulated, and puzzles that require more interpretive skills or were more involved such as using snare to grab an IVC filter attached to a key that opens a lock.

DISCUSSION

The Escape Room format that we designed was appropriate to welcome new radiology residents to the program and to encourage team-building and camaraderie. This format can be adjusted for lower level or upper level residents to test their radiology knowledge and skill set under pressure. The puzzles and clues have endless possibilities and could be tailored to any section of radiology, for example, a gastrointestinal/genitourinary board review session for R3 residents, or a basic musculoskeletal review for R1 residents. Additionally, an Escape Room activity could easily follow a traditional didactic style lecture to reinforce the specific teaching topics.

Most medical education innovations aim to develop the adult learner into a self-starter, problem-solver, and critical thinker. Our players perceived the Escape Room as a valuable educational activity that required critical thinking, teamwork, and the use of interpersonal communication skills to succeed (20). The most common learning outcome common to all team-based escape games is improved teamwork and communication. Successful Escape Room teams work together, communicate, and delegate (18). Our postevent survey unanimously demonstrated that it was a fun activity, but at the same time promoted teamwork and communication skills. Our millennial Escape Room players were highly satisfied with this as an educational activity but the learning objectives may not have been as apparent to them. Perhaps that is because we over-emphasized the fun aspects during our promotional activities.

Based on our survey, players preferred a learning based game to a didactic lecture. As graduate medical education evolves, alternative curricula and teaching methodologies are being tried and evaluated. Research on instructional methods has shown that discussion is more effective than lecture for retention, knowledge transfer, problem solving, and attitude change (21). Using games as part of the curriculum may enhance retention and reinforce learning by creating a more dynamic educational environment (7). Millennials are not inherently motivated to learn from textbooks alone or by passively watching PowerPoint presentations during conferences. They want to be connected and stimulated to participate.

Providing a way for residents to engage with each other after the game definitely enhanced the learning experience (18,22). We intended that players, for whom relevance is important, would discover meaningful connections between the Escape Room activity and real life. They did make connections to being on call, reporting, and performing hand-on procedures. However, on the postevent survey they did not relate the debriefing process to checking-out with staff at the end of a shift. Nor did they recognize the similarity of information needed to solve puzzles to information needed to work in the radiology department. This may indicate that we need to better correlate the information needed to solve puzzles to the practice of radiology, one area for improvement suggested by survey respondents.

Our experience corroborates educators who believe gamification can foster the student-professor relationship (23). Residents reported they valued interacting with the faculty and showing off their competitive skills. This may be

TABLE 2. Escape Room Skills Reflective of General Competencies

General Competency	Expected Outcome	Escape Room Correlate
Patient care and procedural skills	Provide patient care that is compassionate, appropriate, and effective	Multi-task and generate differential diagnoses under extreme stress and time pressure (being on call)
	Perform safe, efficient, appropriate, quality-controlled diagnostic and/or interventional radiological techniques	Dexterity and motor skills required for some puzzles (hand-on procedures)
Medical knowledge	Established and evolving biomedical, clinical, epidemiological and social-behavioral sciences including physics principles	Recall and analyze radiology knowledge under pressure with limited time (being on call)
	Non-interpretive skills, such as the business of medicine, QI, radiologic/pathologic correlation, safe use of contrast agents and pharmaceuticals	
Practice-based learning and improvement	Self-identify strengths, deficiencies, and limits in knowledge and expertise	Reflect on personal performance, considering strengths and weaknesses, and plan future actions accordingly
	Set learning and improvement goals and identify and perform appropriate learning activities	
Interpersonal and communication skills	Communicate results of examinations and procedures effectively and in a timely manner	Communicate effectively (conveying results and recommendations)
	Work effectively as a member or leader of a health care team or other professional group	
Professionalism	Perform responsibilities and adhere to ethical principles	Respect the opinion of your peers
	Professional interpersonal interactions	
Systems-based practice	Work effectively in various health care delivery settings and systems	Able to cooperate and ask for help from colleagues

explained in part by Maslow's theory which would suggest these interactions satisfy the residents' motivational needs for achievement and affiliation (24). We observed that the game created a team dynamic similar to that generated by the Vydareny Imaging Interpretation team competition which is always one of the highlights of the annual AUR meeting. We did find that it was important to review the rules thoroughly before starting the game, as it is surprising what people will do to try and beat their competition.

A recent systematic review of the literature on educational games concluded that games have positive impact on the teaching/learning process and can be used as a context for formative assessment, but robust research is needed to address the use of games that have been assessed objectively (7,10). Assessment tools need to fully capture the learning that may be occurring in the games. The flexibility in Escape Room design suggests they could conceivably be used to assess any skill or attitude required in professional practice when tailored appropriately (6). Noninterpretive skills and attitudes that are vital in practice, for example, cooperation and the ability to ask for help from colleagues when required could also be observed in an Escape Room similar to observations of clinical skills in standardized patient encounters. We were encouraged that residents demonstrated increased grit after participating in the Escape Room. Future observations of how long it takes individuals to ask for help could teach a lot about that resident group.

It has been suggested that there may be a knowledge gap between what gamification is and beneficial applications in the health care setting (9–10). When we began our project in 2017 there was no literature on Escape Rooms in health professions education. Since then, the use of Escape Rooms as a teaching method have been reported by Emergency Medicine (19), Nursing (20,22,25,26), Pathophysiology (27), Pharmacy (5,28, and Vascular Surgery (6)). We are pleased to add our experience, the first reported in Radiology, to this growing body of work.

Limitations of our RSNA survey include the small number of participants, all of whom were attending the same meeting, which may limit results based on user and training bias. Limitations also include data collections from more national conferences and other universities prior to publishing. Additionally, all the games were played in the same setup and space, which may vary at different venues. We also lacked a control group. We adapted pre-existing instruments to assess resident satisfaction, motivation, learning, and skills. There is

likely inherent bias in the survey as the root of each question automatically assumes positive attributes in most of the items. It would have been more objective to have provided a neutral stem.

CONCLUSION

Our findings support the positive impact of gamification on the teaching/learning process for millennial learners in graduate medical education. It is feasible to create a portable, inexpensive Escape Room as a novel educational platform for radiology residents that promote learner engagement through collaboration, creativity, and critical thinking. Our Escape Room, the first reported in radiology, can be adapted for any graduate medical education specialty. It is easily adjusted for different knowledge levels and, because our game is focused on teamwork and communication, it could be used in interprofessional education to foster collaborative practice.

ACKNOWLEDGMENTS

The pilot project was funded by the 2018 APDR Jerome Arndt grant from the Association of Program Directors in Radiology. Preliminary findings were presented as a poster, Team Building in the Modern Era: A Radiology Escape Room, at the Association of University Radiologists 67th April 9-12, 2019, Baltimore.

Grant support allowed us to retain the services of Adam Clare and Denis Coyne of Wero Creative, a Toronto-based game studio, who provided design expertise including theme, puzzles, and set up instructions.

We wish to acknowledge the contribution of Brenda Arsenault, MA, Senior Manager for Survey Research and Program Evaluation, RSNA Department of Research, who administered the postevent survey. Your skills and advice were extremely valuable. Thank you!

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