A gamified training tool for Ebola public health emergency preparedness

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Abbreviations

CDC	Centre for Disease Control
ECDC	European Centre for Disease Control
HOTS	High Order Thinking Skills
LOTS	Low Order Thinking Skills
MSF	Médecins Sans Frontières (a.k.a. Doctors Without Borders)
NGO	Non-governmental Organisation
PHEP	Public Health Emergency Preparedness
PPE	Personal Protective Equipment
WHO	World Health Organisation

Executive Summary

The 2014 Ebola outbreak showed the world that in situations of crisis, preparedness is key. They require a quick and coordinated response from the plethora of actors involved, all with different backgrounds and priorities. To ensure this, training on emergency issues must be effective, engaging and collaborative – a specialty of gamified educational tools. This project aimed to develop one such tool – Ebolution – an online serious game exposing learners to how an Ebola outbreak develops, and the critical actions required to minimise harm. It targets a varied audience, raising awareness of the importance of preparedness no matter one's role. Designed to be played in multi-disciplinary teams, it encourages inter-sectoral collaboration, developing communication, problem solving and decision-making skills essential in crisis situations. Development was done in close cooperation with a variety of stakeholders, including experts in fields such as Ebola, emergency management, education and gamification, as well as potential end-users such as community members and healthcare workers in West Africa. This ensured the tool was relevant, and aligned well to real needs. Through testing with these stakeholders Ebolution has shown to be effective in meeting its objectives. After integrating feedback, the tool has the potential to be modified to target broader populations and address different emergency management situations, working to help in the battle against crises worldwide.

Introduction

In recent years, a spate of global disease outbreaks has put to the test our preparedness to successfully manage public health emergencies. Oftentimes failures are the result of a lack of effective communication and coordination between diverse groups of responders, particularly those working in fragmented health systems. In times of crisis, speed of response is critical – people must know what is required of themselves and others, to ensure a quick and unified approach, tackling the problem from all angles at once.

The West African Ebola virus outbreak of 2014 is a textbook example of one such failure. Though nearby countries in equatorial Africa had experienced Ebola outbreaks for nearly four decades, West African nations were woefully unprepared. Ebola was unfamiliar and unexpected to clinicians, allowing early to remain undetected for months (1). Health authorities documented cases of Ebola-like symptoms, but this information did not reach surveillance teams (2). By the time disease presence was confirmed, it had spread from isolated, easy-to-contain rural areas into densely populated urban centres. Here, the opportunity for transmission was unprecedented (3).

Health workers, whose already scant numbers were as little as one-tenth of the WHO recommended thresholds (1), began dying in droves thanks to lack of experience with Ebola outbreak management, and limited access to adequate personal protective equipment (PPE) (4). Others walked off the job for fear of contagion. Those that remained were subject to violence from the public, whose fear and mistrust was exacerbated by the arrival of strangers in space-suits, carrying away their loved ones to never return. Governments deployed military forces to enforce quarantines and curfews, provoking riots and fuelling conspiracies amongst a public with low health literacy. Next, travel related cases appeared in the US, UK and Europe, and it was declared an international emergency. By the time the emergency status was lifted, almost 30,000 cases had been diagnosed in West Africa, with over 11,000 deaths (3). It was the largest and most deadly Ebola outbreak in history.

Though the outbreak was a spark in a powder keg of poverty and crumbling health structures, failures in the early methods of response would have unquestionably benefited from improved

preparedness. Public health emergency preparedness (PHEP) is a nascent field, aiming to bring together expertise, techniques and organisational principles from the full breadth of fields necessary for an effective response to complex health events (5). It acknowledges that the goals and measures of an emergency response must be distilled into a comprehensive but accessible format that is widely integrated. PHEP typically falls into the realm of public health workers, but as was acutely demonstrated in the Ebola outbreak, is the responsibility of many beyond this field. Without the engagement of government health officials, healthcare workers, non-governmental organisations and the community, any effort will fall short of the mark.

Unfortunately, delivering this message into other arenas can prove difficult. Where it is not one's primary focus, there is a lack of time and interest in engaging in what is often a tedious and pedantic learning exercise. Conventional training involving lectures, readings and examinations proves limited in its ability to capture attention and enforce retention.

In recent years, gamification or 'serious games' have begun to be integrated into a wide range of contexts including education and training, and have showed success (6). Introducing a gaming aspect has some important advantages. First, it improves engagement by promoting emotional involvement with the content – eliciting curiosity, competitiveness and pride. Retention is also enhanced as players navigate complex situations through active experimentation, promoting critical thinking and problem-solving skills. When done in a group environment, gamification encourages effective communication, leadership and collaboration. (7) In a field like PHEP, where one must unite participants from a variety of different backgrounds and engage them in content that may be far from their usual interests, gamification may prove to be an invaluable tool to enhance learning.

From the outset, the 2014 Ebola outbreak lacked two of the pillars WHO defines as fundamental to a successful epidemic response – coordination and communication (8). Had there been better lines of contact between crucial response agencies, and had the various actors better understood what was required of them, it would have been easier to contain. This would not have solved underlying issues of resource deficits, but by abating the fear and stigma surrounding the issue, the management process would have run more smoothly. A gamified preparedness training tool

could be used to bridge this gap. In countries that are threatened by epidemic outbreaks, Ebola or otherwise, introducing a gamified training element into preparedness would bring together actors from the diverse range of implicated fields, and engage them with the required outbreak management processes in a dynamic participatory environment. They would be allowed to experiment and make mistakes within the safety of a simulation. It would demonstrate to them the importance of a collaborative and well-coordinated approach, combining many areas of expertise to find the optimal management plan. By raising awareness of the people and processes essential in responding to disease outbreaks, it would ready them for quick and efficient action should a public health crisis arise.

Objectives

In response to the aforementioned issue, the objectives of this project were:

- To co-design, in collaboration with relevant stakeholders and experts in the field, a prototype of a gamified PHEP training module around an Ebola outbreak. It will target a varied audience and aim to raise awareness of PHEP importance, encourage inter-sectoral collaboration, develop problem solving skills in crisis situations, and increase preparedness.

- To evaluate its content, feasibility and utility by expert and end-user opinion in a range of populations including a West African context, and integrate feedback into further prototype development.

Methodology

Literature Review

A comprehensive, non-systematic search of peer reviewed and grey literature was carried out to generate the Ebola-related content for the game, as well as to inform the game design and mechanics.

Search terms:

PubMed

- Ebola AND emergency preparedness
- Western Africa AND Ebola
- (Game mechanics OR gamification) AND health

Google and Google Scholar

To widen scope to grey literature such as guidelines published by the WHO, CDC, ECDC, the following search terms were used in a range of combinations

- Ebola or EVD or Viral Haemorrhagic Fever or VHF
- Guidelines
- Emergency preparedness or emergency management
- West Africa or Ghana or Liberia or Sierra Leone or Guinea

To examine literature and sample existing gamified health learning tools, the following search terms were used in a range of combinations

- Serious games or gamification or gamified learning or learning games
- Game mechanics
- Health or healthcare
- Outbreak control or epidemic control

Game Development

The design process was guided by the Stanford Institute of Design's Design Thinking methodology (9). It consists of five steps, which are cyclical and iterative (fig. 1).

1. *Empathise*: Understand the context of the issue and the needs of the target audience

   Goal: Understand the issues around Ebola awareness and preparedness, specifically in a West African context, including local beliefs and practices.

   Methods: Literature review and semi-structured interviews with stakeholders and experts (tabs. 1-3).

2. *Define*: Define the problem at hand in specifics.

   Goal: Identify specific knowledge and educational methodology gaps. Generate learning objectives. Elaborate the process of an Ebola outbreak in the West African context, taking the 2014-2016 outbreak as an example.

   Methods: Literature review and semi-structured with stakeholders and experts.

3. *Ideate*: Generate ideas for solutions to your defined issue.

   Goal: In a design team, generate ideas for game mechanics, visual elements, integration of content, tailored to the needs of the target population.

   Methods: Discussion in design team, with input from gamification and education experts, as well as stakeholders.

4. *Prototype:* Generate physical prototypes based on ideas for testing.

   Goal: Create the game tool in playable form, including elaborating the variables, integrating the content, visuals and instructions.

   Methods: Work collaboratively in design team, each focusing on their area of expertise but discussing and testing with each other.

5. *Test:* Solicit feedback about the prototypes.

   Goal: Show tool to range of experts and stakeholders, and ask them for feedback. Iterative rounds of testing and re-design. Scope of testing subjects progressively widened as game developed.

   Methods: See below.

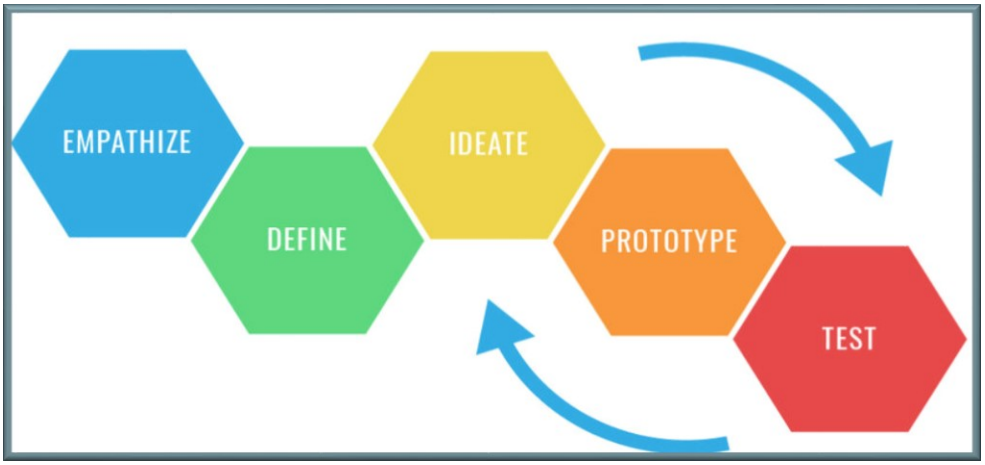

Figure 1. The Stanford Design Thinking Methodology, an iterative approach to people-centred design. (9)

Testing

Although testing of the prototype was carried out constantly and concurrently to development and updating, it can be divided roughly into three rounds, with different testers and goals.

1. Initial tool testing was carried out within the design team (tab. 2) to ensure game elements were functioning as desired, and to develop instructions for gameplay.
2. Second round testing was done with several groups (tab. 3) simultaneously:
    a. Education and gamification experts to evaluate game mechanics, clarity and learning outcomes.
    b. Ebola and emergency experts to evaluate accuracy of the content, and feasibility/usefulness of the tool in their context.
    c. Laypeople and global health students to evaluate clarity and simplicity of the game in the community.
    d. Target audience expert to evaluate appropriateness for West African population.
3. Third round testing was carried out with staff at the Korle-Bu Teaching Hospital in Accra, Ghana. The tool was evaluated by 25 people. Small multi-disciplinary (tab. 1) teams were formed to stimulate cross-sectoral collaboration. Ghana was chosen for testing as it is a West African nation, so has similar culture and practices to the countries of the 2014 outbreak, and thus is likely to face similar issues of control should an outbreak occur. It is naïve to Ebola, and healthcare workers have reported feeling unprepared for an Ebola epidemic despite

government resources having been allocated to training (10). This makes them a population well sensitised to the need for education.

Table 1. Professional profiles of the testing group in Ghana

Player Profiles:		
Nurse (8)	Medical doctor (7)	Midwife (4)
Laboratory Scientist (1)	Laboratory Technician (1)	Driver (1)
Janitor (1)	Optometrist (1)	Pharmacist (1)

Feedback data from testing was gathered by mixed methods questionnaires, including rating scales and multiple-choice questions for quantitative data, and longer response questions for qualitative feedback. Questionnaires were modified based on the round of testing and the desired feedback from the testers, but generally covered the following categories:

1. Clarity, simplicity and ease of use of tool (game mechanics and instructions)
2. Content – accuracy and/or ease of learning
3. Usefulness of tool, application in different contexts
4. Satisfaction and enjoyment
5. Comments and recommendations

Basic statistics were calculated from multiple-choice responses, and text responses were collated and grouped into major themes. The feedback was integrated into each further round of testing where possible.

Questionnaires are available at the following links:
Ebola/emergencies experts:
https://docs.google.com/forms/d/e/1FAIpQLSfZCu8c6I_0B1VZ7tvlsS8aw45yLfZwLCYWxuj8eiht7pXt9g/viewform?usp=sf_link
Ghana:
https://docs.google.com/forms/d/e/1FAIpQLSfGQvswLTCqViMXxY4ypE4IC_NAM6c8pXpdYpM3mEsp5_EpWQ/viewform?usp=sf_link

Other experts, laypeople:
https://docs.google.com/forms/d/e/1FAIpQLSe_jtLE7CmAsrG5R7QZxLE6AttXdCtd9yFPItDtRik_HZEoVw/viewform?usp=sf_link

Stakeholder and Expert Selection

Selection of project participants was based on the diverse areas of need, as established by literature review and discussion with supervisors. These were broadly categorised into design team, experts, and stakeholders, although there was some overlap between the latter two categories; stakeholders were considered possible target audiences of the tool, and some experts in emergency management could fall into this category. Initial contacts were made through existing networks, from which purposive snowball sampling was carried out with each contact asked to recommend at least one other possible contact. Contact with Médecins Sans Frontières (MSF) yielded many expert contacts, along with the game developer for the design team. Testing with laypeople and global health students was done by circulating the game and questionnaire link amongst class communication channels, and within the personal network. Testing in Ghana was arranged by the West African target audience expert through his contacts in his home country.

Table 2. Design team

Name	Position	Selection criteria
Carles Fernandez Barrera	Instructional/E-learning developer, MSF collaborator	Experience in e-learning design with focus on health
Cristián Amunátegui Gutierrez	Graphic designer	Experience in graphic and motion design

Table 3. Experts consulted for input and feedback

Field of expertise	Name	Position	Selection criteria
Ebola	Luis Encinas	HR Director Deputy, Nurse, MSF Switzerland	Extensive (10+ years) experience working with Ebola, including field work in 2014 outbreak
Ebola	Dr. Diana Pou	Doctor at Tropical Medicine Unit of Vall d'Hebron Hospital	Extensive (9 years) field work with Ebola in Africa

Ebola	Dr. Mikel Martínez Yoldi	Senior Specialist in Microbiology at Hospital Clinic de Barcelona. Associate Medical Professor at the University of Barcelona	Research focus in emerging viruses including Ebola in low-income countries
Emergencies in low-resource settings	Silvia Álvarez	Medical Learning Referent, Nurse, MSF Spain	Extensive (10+ years) experience working in emergencies in low-resource settings, both field and advisory work. Experience in training facilitation.
Education	Josep Prior	Head of Learning Unit, MSF Spain	Experience in educational design for low-income settings. Field experience in emergencies.
Education	Rita Sookrit	Learning and Development consultant, MSF Canada	Extensive (20+ years) experience in Learning and Development, including gamification
Gamification	Nadezhda Ilyina	Chief Product Manager, Master Trainer, Kaspersky Lab Security Awareness program	Gamification developer and implementer. Product design and delivery in wide range of contexts
Gamification	Adam Filler	Master Trainer and Sales Director, Kaspersky Lab Security Awareness program	Gamified training delivery and product development.
West African target audience	Dr. Daniel Kwakye Nomah	Medical Doctor, The Community Hospital Ghana. Board Executive, DoctorsAct Ghana. WHO consultant on poverty-related diseases	West African background, with extensive experience in low-income context. Deep understanding of West African audience needs.

Why Design Thinking?

Design Thinking is fundamentally a people-centred approach; it aims to "solve technical problems in ways that satisfy human needs" (11). The idea for Ebolution was itself born out of this notion. Conventional education often does not take into account the needs of the learner, only the goals of the teacher. These goals may be to impart some information, or teach a particular skill, but either way will rarely account for the variety of learning styles and paces. This becomes even more complex and less effective if trying to cater for different backgrounds and levels of pre-existing knowledge. When attempting to create a learning tool like Ebolution that must be accessible and effective for such wide spectrum of learners, it is vital that needs be heard and integrated from the first step. Design Thinking not only allows this, but demands it. Constant collaboration with a wide range of different experts and end-users along the way has facilitated the development of a tool that is learner-centred, allowing them to engage at their own pace, in their own style, and have fun along the way. This meets both their needs and the learning objectives, as motivated learners are known to have better educational outcomes (12).

Another strength of Design Thinking is its embrace of the non-linearity of the design process. Although the methodology is defined in five fairly well-delineated steps, the reality is never so. Many of the steps occur concurrently, and the movement between them is often somewhat erratic (fig. 2). This was evident in designing Ebolution, as the prototype was constantly changed and updated when new input and feedback was received from the many testers and further research. Design Thinking teaches one not fear this seemingly chaotic process, but rather acknowledge it as the true nature of effective collaborative design.

As such, the Design Thinking methodology was an obvious and almost unintentional choice, both guiding and closely following the development of Ebolution, as defined by an ever-evolving process of collaborative design with a people-centred focus.

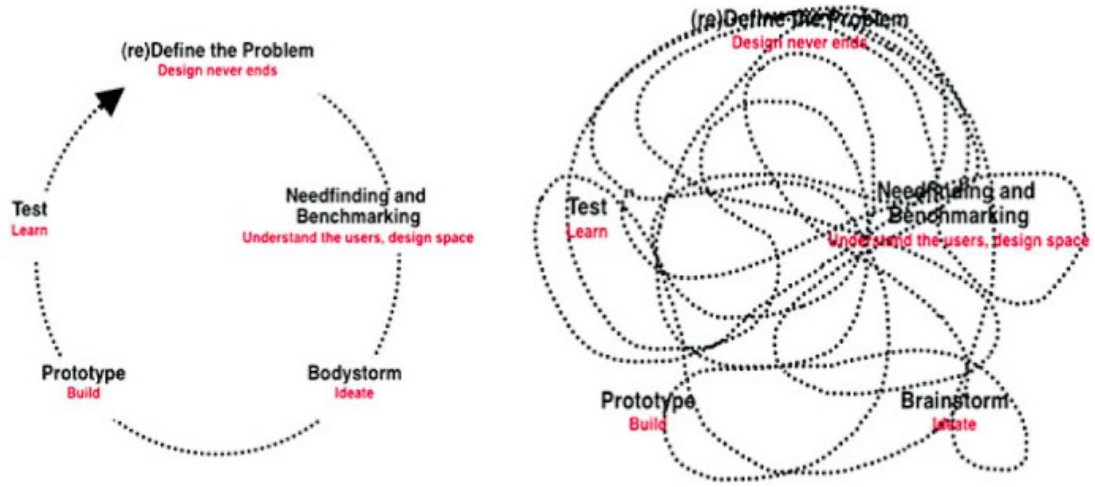

Figure 2. Design thinking expectation (left) versus reality (right). The process is non-linear, with movements between stages often erratic and concurrent.(11)

Design

Ebolution can be accessed at the following link, please feel free to test it out for yourself.
http://indie-learning.com/ebola/story_html5.html

Target Audience

As stated in the Objectives, the goal of this project was to design a tool aimed at a varied audience, in order to make it widely accessible and to encourage inter-sectoral collaboration. PHEP is everybody's business, so in an ideal world the tool would be available to everyone from school children to the high government officials, worldwide. Unfortunately, in scope of this project this was not going to be possible, so instead the focus was placed on groups with vested interest in understanding how Ebola outbreaks work. Through discussion with experts, these groups were established to be frontline workers in potential outbreak areas, community members and global health professionals. These could be healthcare and health-associated workers in countries threatened by outbreaks, NGOs working in such countries, or global and public health workers, particularly those working with topics in outbreak-threatened regions. Through contacts, populations from several of these groups were established, and asked to contribute through both game design and development input, and prototype testing and feedback. This feedback was then

used to identify which elements of the game were more appropriate for each population, and to aid in broadening its reach.

Content

The content of the game, including contextualising scenarios, epidemic response actions, Ebola disease information and gameplay feedback was developed based off the literature search, in particular the WHO and CDC guidelines for Ebola outbreak management (3, 13-16). This was then sent for evaluation by Ebola and emergency management experts (tab. 3) for accuracy and completeness. Initially they were asked to respond to the contextualising scenarios with their ideas of essential response actions, and then to evaluate the actions that had been developed from the literature review. Their feedback led to changes in both the scenarios and actions, and this occurred concurrently with much of the visual and mechanics design process.

Mechanics

As Ke (17) aptly summarises, "the learning game, as a playable fiction, should provide players with positionality (e.g., a professional role), legitimacy in content engagement (e.g., procedural and conceptual content application required by game quests), and consequentiality in a meaningful context (e.g., play actions causing experiential or projective change of the game world)". Ebolution aims to meet these criteria through a combination of game and learning mechanics.

The mechanics of this game took initial inspiration from the Kaspersky KIPS model (18), an online card-board game designed for cyber security awareness training, which has shown effectiveness in many different sectors, and even been integrated into higher education programs (19). Like in Ebolution, teams of players are presented with a challenge, and must select from a range of action cards to counter the effect, in the face of limited resources. In KIPS, the consequences of their chosen actions are demonstrated as lost earnings in the businesses players are trying to protect, unlike in Ebolution where players are preventing deaths.

Such mechanics span from low-order thinking to high-order thinking (fig. 3), and as such engage many different learning pathways. Presenting information and a story or narrative helps players to

discover the context of the challenge, and provides guidance and instruction, stimulating low-order 'retention' and easing players into the game environment. On the other hand, many elements stimulate higher-order thinking skills such as 'creating' and 'evaluating'. Playing the game in teams encourages collaborative discussion and communal discovery, and resource management causes players to develop strategies and reflect on their choices.

GAME MECHANICS	THINKING SKILLS	LEARNING MECHANICS	
○ Design/Editing ○ Infinite Game play ○ Ownership ○ Protégé Effect ○ Status ○ Strategy/Planning ○ Tiles/Grids	CREATING	○ Accountability ○ Ownership ○ Planning ○ Responsibility	LOTS to HOTS
○ Action Points ○ Assessment ○ Collaboration ○ Communal Discovery ○ Resource Management ○ Game Turns ○ Pareto Optimal ○ Rewards/Penalties ○ Urgent Optimism	EVALUATING	○ Assessment ○ Collaboration ○ Hypothesis ○ Incentive ○ Motivation ○ Reflect/Discuss	
○ Feedback ○ Meta-game ○ Realism	ANALYSING	○ Analyse ○ Experimentation ○ Feedback ○ Identify ○ Observation ○ Shadowing	
○ Capture/Elimination ○ Competition ○ Cooperation ○ Movement ○ Progression ○ Selecting/Collecting ○ Simulate/Response ○ Time Pressure	APPLYING	○ Action/Task ○ Competition ○ Cooperation ○ Demonstration ○ Imitation ○ Simulation	
○ Appointment ○ Cascading Information ○ Questions And Answers ○ Role-play ○ Tutorial	UNDERSTANDING	○ Objectify ○ Participation ○ Question And Answers ○ Tutorial	
○ Cut scenes/Story ○ Tokens ○ Virality ○ Behavioural Momentum ○ Pavlovian Interactions ○ Goods/Information	RETENTION	○ Discover ○ Explore ○ Generalisation ○ Guidance ○ Instruction ○ Repetition	

Figure 3. Common game and learning mechanics classified by Bloom's Ordered Thinking Skills (20, 21), from Low Order (LOTS) to High Order (HOTS).

Apart from these core mechanics, several others were added to enhance engagement and learning. A series of quizzes were included which, upon being answered correctly, would increase available resources. These served as a way to integrate educational content into game mechanics such as reward and strategy, a concept known as Intrinsic Learning (22) which has been shown to make games more motivationally and educationally effective. Immediate feedback was also included after players had made their decisions on which actions to take, which allowed players to experiment in a round, but then identify and learn from their mistakes before the game progressed. Immediate feedback is a mechanic that has been shown to improve motivation, sustained attention,

learning and fun (12). After discussion with the design team and trialling of an educational game created by one of the experts working with this project (Silvia Álvarez, tab. 3), it was decided that an element of randomness should be included in the game. This both creates excitement by adding a sense of chance to an otherwise content-heavy decision-making process, and better reflects reality, in which events out of one's control can cause drastic plan changes. These elements will be described in more detail below, in Function.

Visual Design

Collaboration with the graphic designer led to the decision of making the game visuals bright and simple, with the goal to engage learners with a difficult topic in an enjoyable and empowering way (fig. 4). It was felt that using dark colours and overly explicit imagery may frighten people, and as was established early on with Ebola messaging, fear is a highly counterproductive educational tool (4). That being said, weight did not want to be taken from the importance of the content, and certainly did not want it to be trivialised, so whilst the imagery may not have been explicit, the storyline it followed contained realistic detail. The simplicity of the visual design aimed to make the game easy to learn and follow. It was not cluttered, with the location of different objects aiming to be intuitive. This way, players can focus on learning the content and enjoying the challenge, instead of frantically trying to understand the rules.

Learning Objectives

The learning objectives of Ebolution are:

- To develop a basic understanding of Ebola virus disease, including basic biology, diagnosis, transmission, treatment.
- To understand behaviours that promote and prevent transmission, and how they can be implemented on an individual, community and country level.
- To understand some of the critical actions required by a range of different actors in an Ebola outbreak, including:
    - Isolation and case management
    - Surveillance and contact tracing
    - Protective equipment and behaviours

    - Safe burials
    - Communication and cooperation
- To experience and understand some of the challenges faced in emergency management, including:
    - Time and resource constraints
    - Decision making and prioritising
    - Unexpected events in complex contexts
    - Necessity of a multidisciplinary approach
- To increase learners' sense of comfort and preparedness and decrease fear and stigma, through improved knowledge of Ebola and outbreaks.

Function

Gameplay

The game follows the outbreak of an Ebola epidemic in an imaginary West African country, Kwameria. Players' aim is to try to minimise the damage that is done, as counted by number of deaths after each round. Presented with a range of actions, they must make reasoned decisions on which they feel are the most critical in the face of limited resources.

Gameplay consists of four rounds (final rounds in progress), in each of which the scale of the epidemic escalates. The context is given by a short animation before each round. Participants must then select from a range of 8 possible action cards, which are the possible actions they can decide to take in response to the status of the epidemic. On each card, there is a short description of what the action involves.

Each card has a particular cost in resources, money and time, which is listed on the card. At the start of each round, a prescribed budget of each resource is available, and cards must be selected within this budget. The amount of time participants have to make their selection is also limited, and marked by a countdown timer at the top of the screen. Each round, a new set of 8 action cards appear, and although some may be similar actions to previous rounds, their cost may change.

The amount of resources available in a round can be modified in two ways:

In each round, participants have the possibility of earning more resources by playing a quiz, which will test their knowledge relating to Ebola disease. If they answer correctly, they will gain resources (money or time). If they answer incorrectly, they will not lose resources but they will have used some time from the countdown timer. The correct answer will immediately be visible, but will explained in detail the feedback after each round, with a link to further information.

Between each round, there is also a mini-game which triggers an unexpected event. Participants will spin a roulette and depending on the outcome, a positive or negative event will occur. Positive events will increase the resources available in the next round, while negative ones will decrease resources.

After each round, once participants have submitted their final action card choices, they will receive feedback on their selection. The selected cards will be reviewed, commenting on which were well chosen and which were not, along with justifications of why. Participants will also receive a 'score', shown by the number of deaths that have occurred.

Participants/teams can play against others, and at the end of the game the winning person/team is the one which has the lowest overall death toll, i.e. their choice of interventions prevented the highest number of deaths.

Components

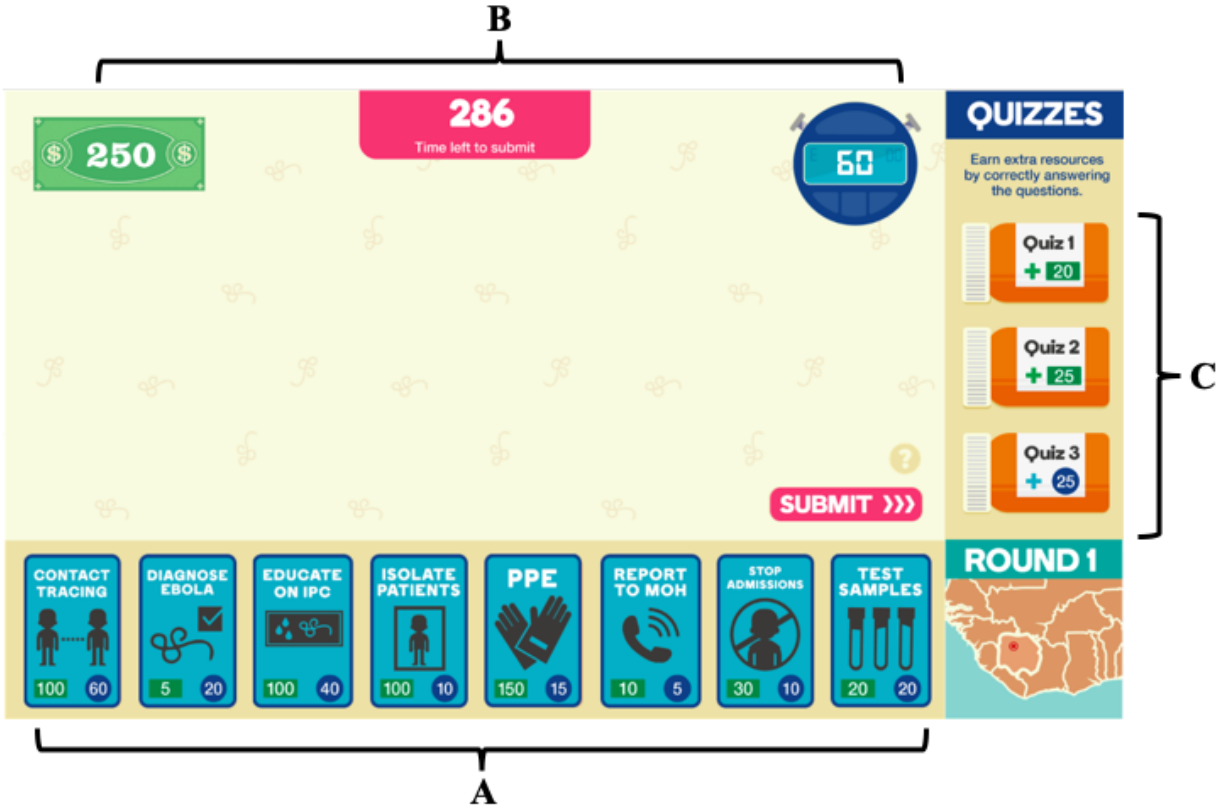

Figure 4. The Ebolution game board, Round 1. A: Action cards; B: Resources – (L-R) money, countdown timer and time; C: Quizzes.

Action cards

Although in an outbreak setting many actions should be taken at once, for this game it was decided to limit the selection of possible action cards to 8 (fig. 4). This was in part for design purposes, as more than 8 cards would be difficult to see properly if playing on a small screen such as a phone or tablet, and also because the more actions are included, the more complex the gameplay becomes both for the developer and the player. The decision was also made to represent the reality of outbreak situations, particularly in naïve settings. All of the required actions are often not immediately obvious, or not possible to execute.

In terms of learning, refining the actions down to the most salient also meant that the content was easier to grasp and more likely to be remembered, as learners are not flooded with excessive information. The explanations were kept simple to ensure accessibility to people with little

background in emergencies, but also aimed to be as accurate as possible. Effort was made to be impartial in the explanations, to avoid implying which were the correct and incorrect choices.

Resources

One of the greatest challenges faced when tacking an epidemic outbreak, particularly in a setting such as West Africa, is that of limited resources. Even in high income countries, health systems are often caught unawares by outbreaks, and struggle to tackle the issue with what they have available. In low-resource settings, this can become unmanageable. As such, it was imperative that a learning tool in this area teach learners about the importance of resource management, and stimulate their critical decision-making capabilities – weighing up both positive and negative potential outcomes of each action with its cost.

Both money and time were included as resources, as both are equally critical to consider in an outbreak situation (fig. 4). One may have all the money in the world, but if the interventions planned do not work quickly enough, the situation will spiral out of control. Likewise, some interventions may be very expensive but have a quick effect, whilst others may be relatively inexpensive but require more time to execute. Most often, they are both expensive and time consuming, so the decision to implement one over another will come down to which is thought to have greater effect or ease of execution. In Ebolution, the budget of resources available to players increases in each round, as the scope of the outbreak widens, and thus the types of interventions required and the responsible body changes. What can and should be done in a hospital with a single case differs from that at a nation-wide governmental level. Additionally, the countdown timer was included to simulate the time pressure felt by decision makers in the real world.

Quizzes

Although the primary goal of this learning tool was to expose players to the critical actions required to counter an Ebola outbreak, it became clear through discussion with experts that it would also be valuable, and in fact necessary, to include information about the disease itself, and its prevention at an individual level. This would both facilitate the success of larger-scale actions as they would be executed in a better informed and sensitised population, and also give players an added sense of confidence and preparedness if faced with Ebola personally. Presenting this information in a

textual format was to be avoided, so quizzes were chosen instead (fig. 4). This allowed people to test their pre-existing knowledge of Ebola disease, and also facilitated learning from mistakes, a technique well established to be beneficial to learning (23). Rewarding players with bonus resources for answering correctly incentivised players to play the quizzes, as without the bonus resources it was often difficult to arrive at the best possible combination of cards. That being said, feedback from testing did show that sometimes players were discouraged from playing the quizzes due to concerns over limited time, an issue that may be targeted by increasing available decision-making time in rounds. Including the quiz element also better reflected the reality of outbreaks; the better you know the disease you are dealing with, the more it will help you tackle it.

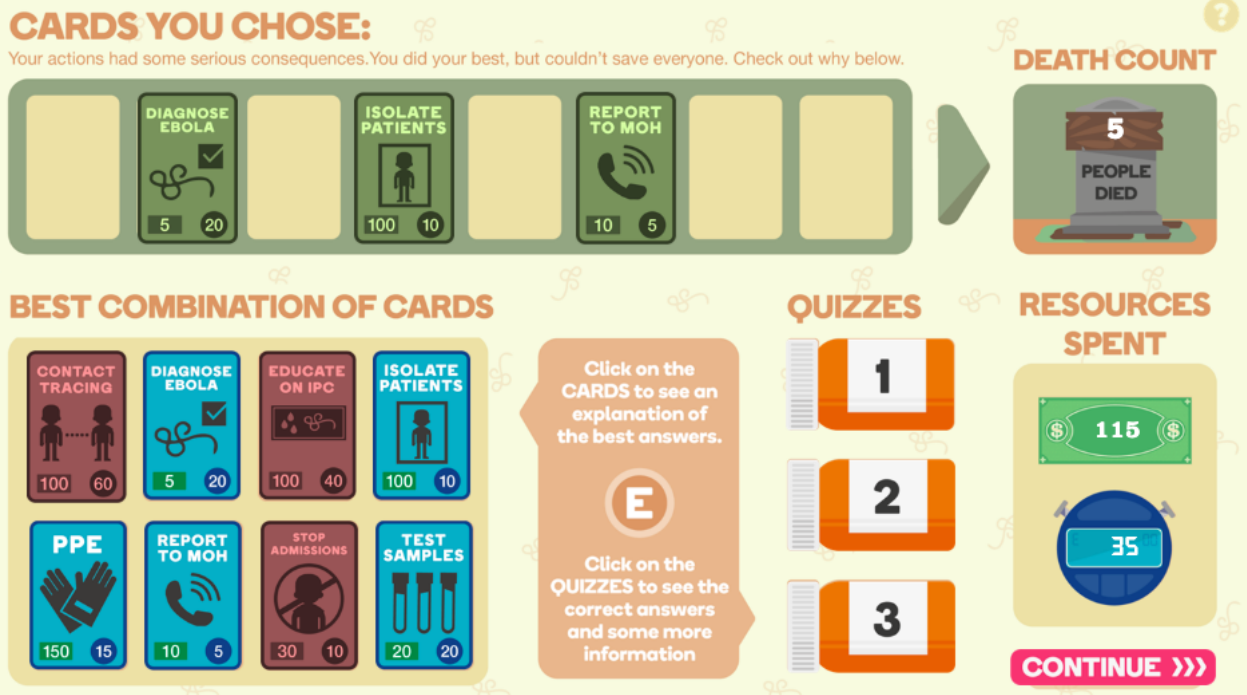

Figure 5. The feedback screen from Ebolution, Round 1. The cards played by the learner in the previous round are shown in the top panel. The best combination of cards is shown beneath, with correct cards in blue and incorrect ones in red. Clicking a card generates a pop-up with more information. Likewise, clicking on a quiz pill boxes gives more information on the quiz answers. The death count 'score' is seen in the top right corner.

Feedback

The feedback section was perhaps the most important component of the game, as it was here that knowledge was consolidated, and players were given justifications for the validity of their choices (fig. 5). A key element of making 'learning from mistakes' effective is corrective feedback (23).

By going through each card in detail, and explaining the reasoning for why it was or was not a good choice, players are not only given explanations for their choices, but also for other cards that they perhaps had not considered. Links were also provided to further information, should the player feel like they would like to know more, or have it explained in a different way. Likewise, with the quiz feedback, the correct answer was elaborated on, and links provided to further learning resources. It was decided that giving feedback immediately after each round was more effective than giving it all in the end, as this ensured the concepts were still fresh in the learner's memory when consolidated. It also meant that players could improve as they went through the game, if they applied the knowledge and ideas from previous rounds. Having a 'death count' as the scoring system was perhaps somewhat grim, but very reflective of the reality of the situation. The mark of a successful epidemic control is the number of people who do not get sick and die, so saving lives was an obvious choice of metric. By making it only a small component of the feedback and not the focus, it maintained some competitive element, but took the attention away from scoring as the most important outcome of the game.

Figure 6. The roulette 'bonus round' after Ebolution Round 1, here showing a positive outcome, a peace treaty, and winning the player both money and time which is added to their budget in the following round.

Roulette

An element of randomness was added to the game in the form of a roulette between rounds, which increased or decreased the resources available in the subsequent rounds depending on the event that occurs as the outcome of the spin (fig. 6). It was made to closely reflect chance events that might happen during an Ebola outbreak in West Africa that could impact resources available for epidemic management and may cause reconsiderations in decision making. Events could be negative, such as rebels seizing medical supplies or media hysteria causing panic and subsequent riots. Positive events included options like receiving donations of funds or humanitarian aid by bodies such as MSF and USAID, or research breakthroughs providing better treatments. The introduction of an element of chance also gave more of a 'game' feel to the players, breaking up the flow of information with a chance to test their luck, rather than their brains.

Results

Expert Validation

The experts listed in table 3 were asked to test the game and give their feedback. Most responded via questionnaire, although a few gave their feedback in written form via email correspondence. Some were asked for further details on their comments, mostly by email but few were interviewed in person (Rita Sookrit, Adam Filler, Dr. Daniel Kwakye Nomah). In all responses, the five general areas listed in Methods – Testing were covered. They were also asked to pass the game and questionnaire link on to other colleagues they felt would be interested and useful to the project, so some feedback was received anonymously from other experts, predominantly in the Ebola and emergency management fields.

Overall the feedback was positive, with all experts commenting that they found it enjoyable, that the tool presented an effective way to learn about decision making in Ebola and could be expanded into other diseases and emergency situations. They commented that the current target audience of health and emergency related staff was appropriate, but that it could work well in the wider community. Other specific recommendations were given based on their area of expertise, and are elaborated below.

Instructions

As discussed, different people have very different learning styles, and this holds true for how they learn to play a game. As such, the instructions were perhaps the most commented element of the game. Some experts felt they were too long, others felt they were too short. Some preferred them as a hands-on tutorial, others asked to include them written out in text. They say you can only please some of the people some of the time, and this is evident here. Despite this variation, particular comments did stand out as the most frequent and salient.

1. The objective of the game being to prioritise the best combination of cards (rather than try to choose them all) should be stated explicitly.
2. The priority between the quizzes and the selection of cards is not immediately obvious
3. Clarification of the player's specific role in the process – although this was mostly a comment from the Ebola/emergencies experts who work with very defined roles.

Gamification and Learning

Gamification and education experts felt that the e-learning field was being used well by this tool, and was effectively targeting an area of need. The game mechanics selected were thought to be appropriate, and introduction of extra elements such as the quizzes and roulette were appreciated. Beyond some minor aesthetic fixes, again the most prominent comments took issue with the way the instructions were presented. Like with other experts, they felt the objective of the game was not sufficiently well elaborated, and that the different elements of the game board needed more detailed explanation. The instructions are perhaps the most important part of a game, as without them players cannot begin to extract the information being presented to them. Following the comments provided by the experts, they will be rewritten and reformatted to increase ease of use. Once gameplay was understood, the response to the content and teaching style of the game was positive. The actions were considered well explained, and feedback detailed but succinct. Experts felt this did allow it to successfully meet the prescribed learning outcomes.

Content

The review of this element was done by experts in Ebola and emergency management. All felt that the information in the action cards was well explained and sufficient, although some mentioned additional actions that could have been included. One such was that of human resources. Health

worker shortages are most acute in sub-Saharan Africa (24), where Ebola outbreaks have occurred. Many of the actions required, both in reality and in the game, would not be possible if the workforce to carry them out was insufficient. Another was the idea of referral and surveillance systems, so crucial in an Ebola context. Both of these were ideas that were going to be explored in later rounds of the game, but their importance is perhaps great enough to be considered from the outset. As discussed in Design and Function, it was decided to limit the actions available in each round for both design purposes and to reflect reality, so in order to integrate this feedback accurately, a larger sample size of experts would need to be consulted to establish a consensus on the true top priorities, and ensure these are presented at appropriate points in the game. Similarly, with the feedback content, some experts felt it did not line up entirely with their understanding of certain actions, or that it required more detail and complexity. This would make sense in a high-level healthcare worker context such as theirs, but if the target audience is to broaden beyond this population, simplicity will be key. Despite this, several commented that game reflected well the reality of such outbreaks in the field.

Community

Testing with non-health worker populations was important for this tool for a number of reasons. First, they were critical for picking up any faults or glitches in the game programming that needed to be ironed out before testing with expert populations, as this would make their experiences smoother and allow them to focus on their area of expertise. Second, as laypeople's attention was not specifically directed to one element of the game, their feedback would give a more general overview of its clarity and playability. Lastly, as the game could have the potential to be expanded into the community, testing with laypeople was a good way to gauge the effectiveness in such a population, in terms of simplicity, ease of understanding and ability to meet learning objectives.

As with the expert population, all of the respondents found the game enjoyable, and considered it an effective way to learn about Ebola decision making. They also all agreed it could be used effectively to educate about other diseases and emergency situations.

Instructions

Although 85% of respondents said they found the game easy to learn and the instructions clear, as with the experts several left comments for improvements. Overall the main comment was that it was taking several tries of the instructions and some practice in the game to get a good understanding, and a bit more detail in the instructions would make this process faster. They also picked up a glitch with the timer, which was already running in the tutorial and did not refresh once the round had started, causing people to rush through the instructions. This was fixed before further testing, and perhaps why later trials did not emphasise confusion with the instructions.

Learning Objectives

Before the outbreak, 75% of respondents considered their understanding of Ebola outbreaks and the actions required to be poor or average. After playing the game, all stated their understanding had improved, although 50% of these said it only improved a little (fig. 7). All respondents felt more prepared should an Ebola outbreak begin in their country, although only a little (50%) or somewhat (50%). Despite this, all agreed that the information in the game was of high enough quality and sufficient depth to give someone with limited prior knowledge a basic understanding of how Ebola outbreaks work. These are good indicators that the game could be successful in the community, as it met the learning objectives of improving Ebola outbreak understanding and sense of preparedness.

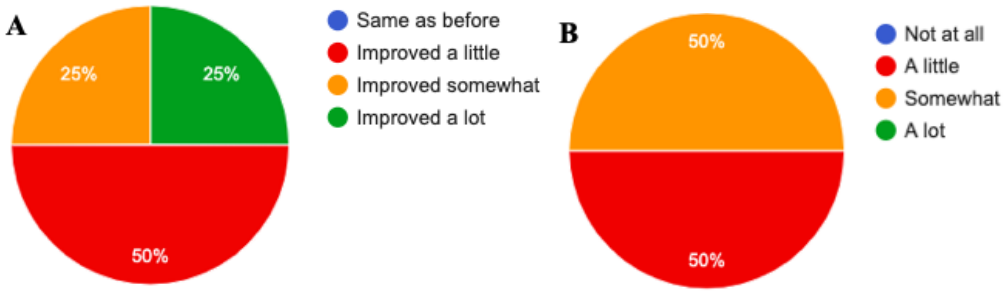

Figure 7. Responses from the layperson testing population to learning outcome-based questions; **A**: "After playing this game, how much better is your understanding of Ebola outbreaks and the actions required?" **B**: "After playing this game, how much more prepared would you feel if an Ebola outbreak began in your country?"

Target audiences

The target audiences respondents felt would most benefit from this tool fell broadly into three categories: health workers, health students and the general population. 62.5% of people mentioned healthcare workers in their response, with 40% of these specifying lower-level staff. One person also mentioned social workers, another NGO workers, and a third public/global health professionals. 25% of respondents mentioned it would be appropriate as a teaching tool for medical and biomedical students. Half of respondents said it would be appropriate for the general population, although one did mention it would need to be simplified somewhat. One person specifically mentioned young people as a target audience, as they have the computer skills required and enjoy computer games. These responses further demonstrate that the tool could have a beneficial effect in broad populations.

Ghana

Satisfaction

Overall, feedback results from testing of the tool in Ghana were very positive, the most of all the testing populations. 83% of respondents found the game fun, and 94% said they would be likely to recommend this game to others to learn about Ebola outbreak management. No respondent said they were dissatisfied with the game.

Gamification

All respondents considered learning through gaming very enjoyable as compared to conventional learning tools, and 94.4% said they felt learning through this medium helped improve their learning and retention. All considered an online board game to be an effective way to learn about Ebola decision making except two, who raised concerns about internet availability in some areas limiting accessibility to the tool.

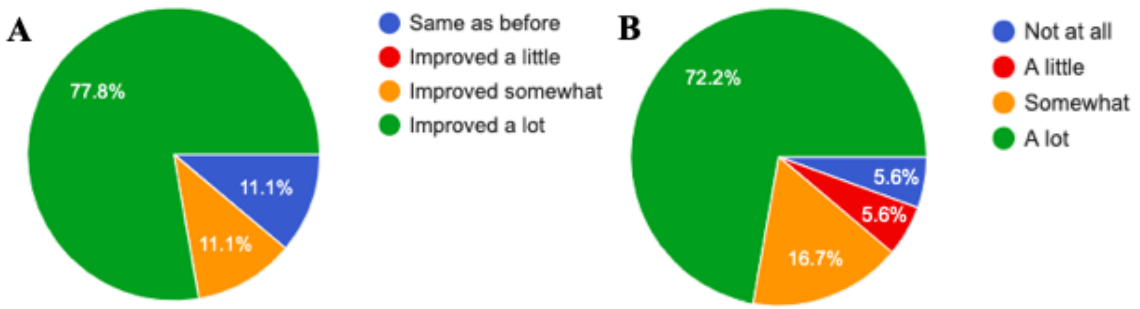

Figure 8. Responses from the Ghanaian testing population to learning outcome-based questions; **A**: "After playing this game, how much better is your understanding of Ebola outbreaks and the actions required?" **B**: "After playing this game, how much more prepared would you feel if an Ebola outbreak began in your country?"

Learning objectives

In terms of meeting the learning objectives, before playing the game, 61% of respondents rated their understanding of the actions that should be taken in an Ebola outbreak as poor or neutral, and 39% rated their understanding of the 2014 West African Ebola outbreak as poor or neutral. After playing the game (fig. 8), 77.8% of respondents said their understanding of Ebola outbreaks and the actions required improved a lot, and a further 11% said their understanding improved somewhat. 94% said they would feel more prepared if an Ebola outbreak began in their country, of which 72.2% said they would feel a lot more prepared.

Instructions

Unlike in the expert population, 89% of respondents in Ghana considered the game easy to understand, and the rules clear. A further 11% (2 responders) were neutral on this point, mainly because they were not sure which element of the game to begin with – the quizzes or the cards. This point is echoed by the expert feedback.

Cards

72% of respondents felt the action cards were well explained with sufficient information to make decisions, but this meant over a quarter of respondents were not confident making decisions of actions with the information provided. This also mirrors some of the feedback received from other testing groups, and warrants attention for future updates.

Feedback

Similarly in the feedback section, about a quarter of respondents (27%) did not feel it was entirely clear, or mentioned that part of their team or certain potential target groups (particularly in isolated communities) would struggle to understand it due to education levels. Several also mentioned language difficulties for people in rural areas, where English may not be as widely spoken. Only 61% of respondents felt that a 'death count' was an appropriate scorings system, with the rest remaining neutral on the issue.

Group dynamic

Part of the objective of this project was to create a tool which encouraged inter-disciplinary collaboration and decision making, and as such the Ghanaian testing group were asked to trial the tool in groups of at least two, and up to four, with mixed teams of players from varied professional backgrounds (tab. 1). Most seemed to prefer this style of gaming, with 55.6% stating they would prefer to play in a small group, and a further 16.7% preferring pairs. Two thirds agreed that discussion in a team made it easier to make decisions on which actions to take, which is a good indicator that the game works well to meet the objective of understanding the necessity of a multi-disciplinary approach.

Transferability

In terms of transferability of this tool for education on other diseases or emergency situations, again all except two respondents (89%) felt that the tool would be transferrable. The two respondents who did not think so were the two who had raised concerns about internet accessibility, so it was more to do with the context than the tool itself. When asked which groups would benefit from such a learning tool (fig. 9), responses were varied, but fell into roughly three groups. Almost two thirds of the respondents (63%) felt the target audience should be broadened beyond health-related professions to include everyone, and of these almost half (42%) specified taking it to the community (laypeople). Some people identified particular community groups that they thought would most benefit, those being youth and pregnant women and their husbands. As these are particularly vulnerable groups but also groups with frequent contact with health and educational facilities, this could be an effective avenue for expansion. The remaining 37% of

respondents felt it was more appropriate for health professionals, with one person specifying it should target healthcare workers in training, to have them enter the workforce prepared.

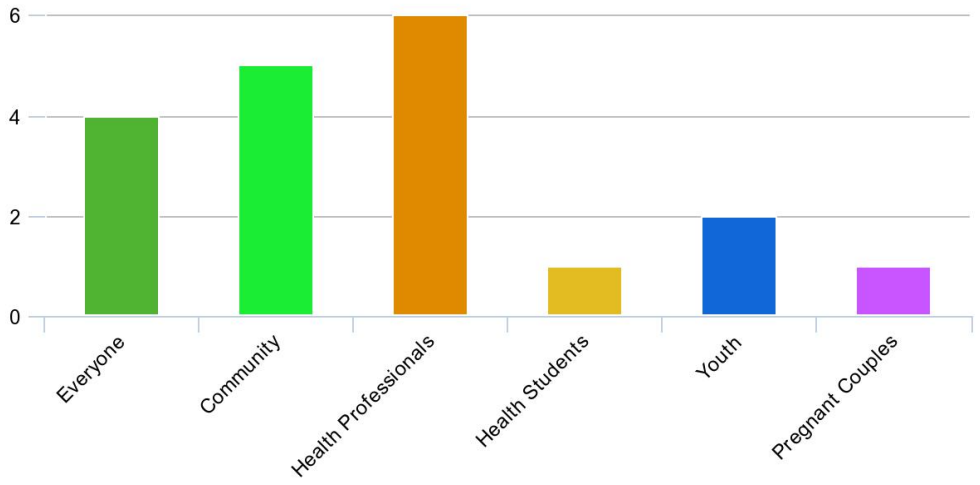

Figure 9. Groups identified by Ghanaian respondents as likely to benefit most from a learning tool like Ebolution

From the comments left in the open-response section of the questionnaire, suggestions and recommendations were extracted and categorised into strengths and areas of improvement.

Strengths of the game included:

- Easy to do in a short time (e.g. on a break)
- Entertaining ("looks just like normal entertainment" "but you learn")
- Broadly applicable – many comments called for versions targeting different issues ("the things that are killing Ghanaians now"), including HIV, Malaria, gender issues and road accidents. One comment even suggested nation-wide implementation starting through high schools to give the tool visibility, and expanding into the health service.

Areas of improvement identified were:

- Age acceptability – several comments mentioned this learning format worked better for younger players ("good if in a team with young people"; "older professionals in my ward didn't want to really participate"). This was evident in that 61% of respondents were under 30 years old, despite people of all ages being asked to participate.

- As mentioned, several comments raised concerns about internet availability limiting access to the tool, particularly in Ebola-affected areas. The game is currently available in an offline format, in that it can be pre-loaded when internet is available and then played without connection, but this may still pose issues if internet is completely inaccessible. In this case analogue training methods are likely to be the only option.
- One comment called for more in-depth detail on the disease itself, which was designed to come through the quizzes, but as only two rounds were complete at the time of testing not all of the desired information was presented.

Feedback Integration

From the feedback received, it is evident that certain elements of the tool require further elaboration. The element that received the most attention was the instructions, so this will need be the first area modified. The comments on how the instructions should be presented are greatly varied, so in order to cater to the broadest audience it would be best to try to meet as many learning needs as possible. In the instructions section, this could be done by including several different formats of explaining the game. For those who prefer to read an in-depth description, an 'About the Game' button could be included on the opening screen, which takes players to an instruction manual. The tutorial-style instructions currently in place will be reviewed for clarity, and details added where comments have mentioned confusions – particularly regarding the quizzes. It may even be better to create a short video of the game being played with a voiceover explaining how it is done. This will be more inclusive of older players, as they may not be as quick to pick up how it works due to less time spent online gaming in their lifetimes.

Comments from experts mentioned the game was missing some crucial actions, though many of these were due to be explored in later rounds. As such, completing the final rounds of the game will be critical to ensure a complete picture is available before the game can be taken further. The final feedback section will also be very important, as this will give players an overview of their progress, and show them how their score compares to the best- and worst-case scenarios via a scoreboard or scale ranking their score. This way they will have a reference point for their learning,

and better understand where they may require further training. It was also mentioned that some more information for individuals was desired, and education expert Rita Sookrit suggested it is valuable to give players a 'take-away' to reflect on the main lessons learnt. This way, they have an easy way to access the critical information whenever they should need it. This could be in the form of a poster or leaflet which summarises the most vital information about Ebola disease, such as symptoms and transmission, which actions should be taken if symptoms develop, sources for further information and emergency contact details. This could even be printed and posted in workplaces, schools or community meeting points to serve as a reminder and reinforcer of learning. All of these modifications are fairly straightforward and have begun to be implemented. Further rounds of testing in broader populations will show whether the changes are effective, and identify further areas for development.

Limitations

Time

The primary limitation in this project was time. Only two out of the four initially planned rounds were fully implemented by the time testing had to begin, and although this did not majorly impact peoples' ability to evaluate the game as a concept, it did mean they could not evaluate it as a whole, or achieve the full range of learning outcomes. Personal expertise was not sufficient to complete all of the visual design and coding, so a design team had to be created. This meant project development was also dependent on the availabilities of other team members.

Contacts

Expert selection was based on pre-existing contacts, or subject to the willingness of cold-contacted participants to engage with the project. Thus, their input and evaluation would have been biased to their experience of the subject, and their conception of priority objectives in the field of Ebola emergency preparedness. Also, contacts were mostly limited to the health, emergency management and education aspects of preparedness. It would have been valuable to have both input and testing in groups such as government and defence, non-health NGOs, and laypeople from

many different age groups and backgrounds. A broader range of input would have yielded a more robust tool, but this was limited by both time and the available network.

Testing

Due to the geographical disparity of the many participants in this project, testing had to be done via an online medium. This was a strength as it allowed feedback to be gathered worldwide, but also a limitation as it meant feedback had to be limited to a short questionnaire that people would be willing to complete. This allowed only the collection of basic data, and few comments. More complete data could have been collected by watching people play in real time and seeing how they engaged with the tool, where they encountered issues, and the group dynamic. This could have been further complemented by conducting interviews and focus groups post-testing. Conducting testing online also meant it was up to the discretion of the tester when they played and reviewed the game, so a data collection timeline was difficult to set. Results and the tool were updated whenever feedback was received, often haphazardly.

Despite all of this, the final sample size achieved for testing and feedback was still greater than initially expected, and covered a broad scope of backgrounds, from laypeople to experts, from Ghana to Australia. The game will continue to be developed, and more feedback will be received and integrated as the contact network expands.

Future Prospects

One of the most prominent recommendations that came out of the feedback was to broaden the scope of this tool into more populations and other preparedness management issues. The format of the game is versatile, and having the mechanics well elaborated it would be relatively simple to modify the content to suit different learner needs or topics. These could include other diseases with epidemic potential, or even natural or man-made disasters. There was a strong recommendation to make the tool available to the wider community and healthcare students, but it could also be modified to be effective in higher-level healthcare professionals, NGO training programs, and ministerial briefings.

To have it be most effective in the recommended groups, particularly in places threatened by Ebola and other outbreaks such as West Africa, translating it into local languages would be essential to make it accessible by community members with limited educational backgrounds. A comment from one of the feedback questionnaires that echoed this recommendation exemplified this, explaining that 'I think the guy I played with didn't understand well though. He is a janitor." With hygiene and waste management a critical part of Ebola containment, a successful educational tool would need to be accessible by janitors as much as by doctors.

Ebolution has shown evidence that it is able to meet its objectives of teaching a broad audience about Ebola outbreak management in a simple and effective way, improving awareness and sense of preparedness. Encouragement to introduce the tool in broader contexts is strong, and has sparked discussion with the West African target audience expert on the possibility of pitching the tool to the Ghana Health Service and the Ghana Education Service. With all the rounds completed, feedback integrated, and the right contacts, the tool has the potential to be applied in a wide variety of contexts. By engaging a spectrum of learners with an innovative educational tool that they enjoy using irrespective of their background, it encourages collaboration and allows them to learn from their mistakes in the safety of a simulation. Ebolution and similar tools could prove effective in helping prevent the horrors of the 2014 Ebola outbreak, or other emergency situations, from ever happening again.

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