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Discussions

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HAZAGORA: will you survive the next disaster? – a serious game to raise awareness about geohazards and disaster risk reduction

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Abstract

Natural disasters are too often presented as resulting from extreme natural phenomena affecting helpless populations, with people being insufficiently aware of the factors leading to disasters and of the existing strategies to mitigate their impacts. We developed a board game aimed at raising awareness about geohazards and disaster risk reduction strategies. The target groups are (1) secondary school students and citizens, and (2) scientists and stakeholders involved in risk management activities. For the first group, the aim is to induce a better understanding of geohazards and disasters they are confronted with in the media or in their daily life; for the second, the objective is to generate discussion about risk management strategies. The game was tested with students in Belgium and with citizens, earth scientists and risk managers in several African countries. Based on the game strategies analysis, the players' reactions during the game and their answers to a short questionnaire, we analyzed the main learning outcomes conveyed by this game. The *Hazagora* game appears to positively enhance the players' insight in processes involved in disasters. As such, the game is an effective playful learning tool to introduce participants to the concept of geohazard and disaster and to generate discussion.

1 Introduction

Disasters causing havocs are repeatedly making the media headlines. However, the media generally focus on the natural component of disasters, giving less attention to the human factors shaping the outcomes of the event. Since the turn of the millennium, the scientific community (Wisner et al., 2003) and the international institutions (United Nations, 2015) recognize that disasters outcomes are mostly controlled by political, economic, social, physical, environmental, and stochastic processes rather than by the event intensity. Exposure and vulnerability to hazards is not the same for all humans (Wisner et al., 2003). The uneven burden of disaster victims in developing countries,

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especially in Asia and Africa (Guha-Sapir et al., 2014), highlight that the political and socio-economic context are essential characteristics influencing the impacts of disasters. Those factors control the capacity of the authorities to mitigate impacts based on scientific risk assessment and preparedness actions (United Nations, 2005). Those same factors also influence the rights one individual or community has to access land and natural resources, its wealth, its access to information and its health (Wisner et al., 2003). Therefore, nowadays disaster reduction strategies do not focus only on understanding and reducing hazards but also on increasing the resilience of societies (Smith, 2013; United Nations, 2015).

The conceptual understanding of the combination of factors that lead to catastrophes and the strategies to address them is not widely represented by the media and in layman discussions, and is not always well understood by risk management actors. In that perspective, we present a new serious game that was created with the objective of (1) providing key scientific information about the mechanisms of geohazards, their intensity, spatial extent, and impacts on infrastructures, natural resources, and livelihoods, (2) highlighting the role played by the livelihood strategy and the access to natural resources in controlling the vulnerability profile of households and communities, (3) triggering discussions on strategies that can be implemented to develop a resilient society able to withstand, and to cope with, the impacts of geological disasters; and (4) being accessible to a large audience of different age, culture, educational background, and experience.

Serious games are designed to support learning and raise awareness on important issues (Boyle et al., 2014; Pereira et al., 2014). Their main purpose is not entertainment but to use the potential of games to get people engaged and motivated in order to transfer knowledge (Susi et al., 2007). Indeed, the traditional learning cognitive approaches where people only think, analyze, comprehend, and learn by heart without trying, touching, and exploring start to be considered as limited and restrictive (Dieleman and Huisingh, 2006). According to Kolb (1984), the experiential approach is essential in the learning process. To learn, new concepts have to be exposed and people

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also need to be engaged, motivated, surprised, and challenged (Pereira et al., 2014; Turkay and Adinolf, 2012). Games have a positive contribution to the learning process because they are heuristic. The players can experience complex situations illustrated by a visual support and test new strategies without having to deal with the real consequences of their decisions (Castella et al., 2005; Dieleman and Huisingh, 2006; Lamarque et al., 2013; Souchère et al., 2010; Susi et al., 2007). The fun environment induced by the game reduces anxiety and facilitates debate between people who are otherwise not always brought together. They can share knowledge, take collective decisions and explore new strategies (Castella et al., 2005; Dieleman and Huisingh, 2006; Lamarque et al., 2013; Souchère et al., 2010; Susi et al., 2007). A game also helps the players to more easily link different processes that the game wants to illustrate (Pereira et al., 2014; Souchère et al., 2010). A game facilitates the development of new personal and social skills and the learning process of new concepts (Castella et al., 2005; Pereira et al., 2014; Susi et al., 2007).

Regarding these characteristics, gaming, as a learning approach, seems particularly relevant in the context of understanding the challenges and complexities involved in coping with natural disasters and increasing resilience. For that reason, we decided on developing *Hazagora*.

In this paper, we first present the structure of the *Hazagora* game. We then explain how the game was tested on different target groups in Belgium and several African countries. Thirdly, the results of these tests are presented, including the contrasted players' strategies, the impact of the game in improving their understanding of geological disasters and their opinions on the game. Finally we discuss the elements influencing the development of new strategies during a game session, the playfulness of *Hazagora* and its usefulness as a serious game in raising awareness about the disaster components and generating discussion about disaster risk reduction (DRR) strategies, as well as the limitations and perspectives of the approach.

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2 The game: objectives, set up and game rules

2.1 Game objective

The objective of the game *Hazagora: will you survive the next disaster?* is to develop a resilient community facing at times geological hazards. The game is based on the hypotheses that (1) a resilient community is one that is able to resist, adapt to and recover from the impacts of geohazards, through the implementation of individual or cooperative mitigation strategies, in a timely and efficient manner (UN/ISDR, 2007), (2) the outcomes of a disaster result from the complex combination of factors including the intensity and the spatial distribution of natural events, the access-to-resources profile of households associated to their livelihood and their settlement location, and finally the capacity of a community to implement preparedness, mitigation, and adaptation risk reduction strategies (UN/ISDR, n.d.).

2.2 Game set up

Keeping in mind that the game is a simplification of real life, *Hazagora* is a board game that displays a volcanic island divided in different land cover areas (Fig. 1a). The central part is occupied by a volcano, surrounded by a forest and by agricultural lands down to the coastal area. Wells and markets, providing water and food respectively, are scattered across the island. Potential locations where players can develop their household settlements and road networks are drawn on the board game. The board game is divided into different sectors which represent areas that can be affected by a geohazard.

The game can be played with 5 to 10 players, at least 15 years of age. It is led by a game master who is following instructions provided in the *Hazagora* guidelines. During the game, the players embody one of 5 characters, each represented by a specific livelihood and color (Fig. 1b): the mayor (red), the fisherman (blue), the lumberjack (green), the farmer (yellow), and the tourist guide (black). The livelihood profile of each

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character limits the potential location of its settlements (e.g. the fisherman is bound to live close to the coastline) and controls its income. At the beginning of the game, players are informed of the presence of water wells, food markets and sectors defining hazard impacts but no information is given about their utility on the island. Players are free to settle down two households and two roads on the island. This defines the locations from where each character will be allowed to expand from.

2.3 Playing the game

The life on the island unfolds in years. A year corresponds to a round table during which players receive an income to support their households' basic needs and make investments. Each game year, the characters receive a specific income related to their livelihood and multiplied by their number of living households. That income is represented by different resource cards: bread, water, and bricks (Fig. 1c). Two additional resources are obtained each year by rolling dices to represent the variable part of the income (Fig. 1d). To survive a year, each household has to be sheltered in a hut, a house or a temporary tent, and its basic needs of food and water have to be met (i.e. one bread and one water). The player feeds and gives water to his households by giving the corresponding resource cards back to the game master. Alternatively, the households that are connected by a road to a water well or a food market (Fig. 1e) freely benefit from these resources and spare their resource cards (Fig. 2). Once the basic needs (food, water, and shelter) are met, the rest of the income can be invested to further develop the character's households. Huts, houses, and roads can be built to expand from the two initial households of each character (Fig. 1f). Each time a player establishes a new hut or a new house, he simulates the settlement of one or two additional households, respectively, on the island. The costs of infrastructure are defined by a certain amount and type of resources (Fig. 1g).

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2.4 Occurrence of geohazards

Geological hazards (i.e. earthquake, tsunami, lava flow, ash fall) occur on the island at variable time intervals. Each time interval is defined by the game master but is not communicated to the players. Through an alarm, the players are informed of the occurrence of a hazard. Several geohazard events in one year are possible. A probabilistic tree allows randomly selecting the type and intensity of the geohazard that will occur (Fig. 3a). The intensity of hazards is defined by an arbitrary 3-level scale for earthquake, tsunami and ash fallout, which corresponds to an increasing spatial extent and/or range of damage. This is not the case for a lava flow. The players then watch a video clip, commented by the game master, which illustrates the hazard impacts based on recent disasters. Based on the video clip and their knowledge, the players are invited to explain the hazard mechanisms and to assess, depending on its intensity, its potential impacts on the elements present on the board game board game, the available natural resources, and the income of the different characters. An impact table helps them to represent schematically those impacts depending on different intensities (Fig. 4). It should be noticed that other impacts than the ones defined within the *Hazagora* guidelines can be proposed by the players and implemented if they correspond to a potential and realistic impact. As already mentioned, the spatial extent of each hazard is also defined, based on the nature of the hazard and its intensity (Fig. 3b). For example, a tsunami of small intensity will only impact the huts located close to the coast. With larger tsunami intensity, impacts will occur at a larger distance inland and will cause more damage: huts will be destroyed but people living in these huts will also be killed, water wells will be contaminated and the fisherman will lose his income. The fallout from a volcanic plume will impact only one sector of the island due to wind direction controlling its dispersion. Fallout will cause pollution of the water wells and will potentially lead to the loss of income of the farmer and the lumberjack characters when ash fall affects the crops and the vegetation. With a high intensity ash fall, huts collapse due to ash loading on the roof and may kill the people living in these huts.

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After discussion, the defined impacts related to the hazard are implemented on the board game by removing the destroyed elements (i.e. huts, houses, roads), the killed households, by making the contaminated resources inaccessible (i.e. water wells, food markets) and by providing no income to the affected characters in the following year (Fig. 3c). In this way, players virtually experience the impacts of the hazards through their character and they are directly confronted with the implications of decisions taken during the game.

2.5 Protective actions and community strategies

In order to reduce the impact of geohazards, each player has the opportunity to acquire "protective actions" which are categorized as mitigation (Fig. 3d), preparedness (Fig. 3e), and adaptation cards (Fig. 3f). Mitigation cards consist of awareness raising actions, monitoring, and warning systems which enable people to recognize the upcoming hazard and evacuate on time. The impacts on infrastructures are still incurred but lives are saved. This is only valid for hazards that may somehow be forecasted with a proper monitoring system. Earthquakes are therefore excluded. Preparedness cards consist of stockpiling essential resources, such as water, food or tents, in order to meet basic needs after being impacted by a hazard. Finally the adaptation cards allow reinforcing and protecting infrastructures against the impacts of an earthquake, tsunami or ash fallout.

Players can acquire protection cards individually, but they can also decide to take actions as a community. Individual protection cards require few resources but to be ready to face the various impacts of the different hazards, a player has to buy several of them. Moreover, individual protection cards can only be used by the owner of the card and cannot be shared to help another player in need. Community protection cards, on the other hand, require more resources, corresponding to the equivalent of three individual protection cards, but the cost can be shared among the players. The advantage is that less community protection cards are needed because they can be used efficiently by all characters within the sector facing a hazard. Once a hazard is taking place, players

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can decide to use their individual or community protection card to avoid (part of) the impacts. Once used, the card is no longer available to the players.

2.6 Game outcome

At the end of each *Hazagora* year, the game master invites all the actors of the game to discuss the development of the island and the need to take joined decisions to develop the island or protect the entire community against hazards. If a new strategy not defined within the *Hazagora* guidelines is voted, the game master decides of the price to implement it on the board game. This allows the players to test, experience, and discuss new management ideas (see results section).

The game ends after a minimum of 5 years, which enables the players to discover a large panel of different hazards. They can also experience several times the same hazard, which allows testing new strategies. At the end of the game, the resilience of the community is evaluated using a resilience index that is calculated for each individual character and at the community level (Eq. 1). The number of living households with a permanent shelter and an access to natural resources, the number of infrastructures which are still in use on the board game and the amount of individual or community protection cards allow the players to gain capacity points. Those points are then divided by the vulnerability points that a player gets from the number of households homeless, killed during the game, or without access to resources, and the number of infrastructures that have been destroyed during the game. In addition, to evaluate the resilience level reached by the community, the resilience index is also used to rank the players and to generate discussion after the game. Strategies used by the players are then reviewed to explain why a player has a higher index outcome than another one.

$$\text{Resilience index} = \frac{\text{capacity points}}{1 + \text{vulnerability points}} \quad (1)$$

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3 Game implementation and tests

A total of 9 game sessions (75 players in total) have been organized in different countries (Belgium, Comoros Islands, Democratic Republic of Congo and Tanzania) (Table 1). The African countries correspond to places where education and/or research projects regarding geohazards were already being led by the authors. The profiles of the players, aged 16 to 61, were contrasted, involving groups of students (secondary and university), citizens, junior university staff or stakeholders with different academic background and experience with hazards (Fig. 5). As the game was played in active volcano-tectonic regions, the majority of the African players had been confronted at least once with a hazard illustrated by the game, whereas European players usually had no experience with such hazard. The progress of each game session was recorded using a digital voice recorder and pictures were taken to illustrate the development of the households and infrastructures established on the board game at the end of each year and after each hazard. In addition, an observer, different from the game master, took notes to document the remarks and strategies adopted by the players.

In order to assess if the learning objectives of the game were met, a short questionnaire was distributed before starting the game to define the profile of the players, their relation with hazards and their knowledge on the factors influencing disasters. At the end of the game, a second questionnaire to evaluate the players' opinion of the game and their knowledge of the factors influencing disasters was completed. The same set of statements, related to the factors influencing disasters, was proposed in both surveys but in a different order to avoid automatic answering. The player was asked to express his level of agreement with each statement using a 5 level Likert scale. Statements with expected negative and positive answers were mixed. The evolution of answers determined the impact of the game in terms of insights gained on geohazards, and the role of livelihood strategies and access to natural resources in controlling the vulnerability profile of households and communities.

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4 Analysis of game outcomes

4.1 The strategies

The different game sessions allowed observing the development of different strategies of resilience. Not all strategies were adopted in each game session but a combination of some of them was systematically observed. Classification of the players regarding of their age, background and experience cannot be made because strategies adopted during the game (1) are influenced by personal desire to take risk or not, (2) are mostly intermediary to the extremes strategies described below and, (3) are changing during the game.

4.1.1 Fast-growth fatalist vs. protectionist strategies

Throughout the sessions, we observed two main adopted strategies which we refer to as fast-growth fatalist and protectionist.

Fast-growth fatalist strategies are based on the player's assumption that he will be spared from geohazards and/or that the best way to survive potential impacts is by rapidly developing a large set of households. The player spends all his resources to develop new households and limited or no protection cards are collected. No savings are built or planning is made to overcome a hazard or sustain daily life during a calm period. The player tends to have a lot of households to sustain. When impacted by a hazard, or when loosing access to resources due to road destruction, the player can no longer sustain all his households, resulting in death or the need to request help from other players.

On the contrary, protectionist strategies focus on risk reduction strategies and resilient development. A player adopting such a strategy develops his households slowly and saves resources. Several complementary protection cards are collected. Households have therefore a higher chance to survive a hazard and infrastructures are more adapted to resist it. Considering the recurrence of certain hazards, an upgrade of the

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dwelling from a hut to a house allows the protectionist player to make sure its estate properties will withstand impacts from tsunamis and ash falls. He can further make his house resistant to earthquakes using the proper adaptation card. In addition to the basic *Hazagora* rules, some players sensitive to risk reduction suggested diversifying their activities to increase income and cope with the livelihood-targeting impacts. For example, a fisherman living along the coast may want to earn a second income from the upper slope of the island (lumberjack) such that when the fisherman does not receive his income due to a tsunami, he will still receive resources from a livelihood which is not affected by the hazard.

4.1.2 Spatial development of settlements

Players may take account of space in different ways. The location of the initial two households is of major importance. The player might decide to concentrate his initial and subsequent dwellings. Doing so, the player clusters his assets geographically and might face higher impacts once a hazard strikes that area. Alternatively, the player might decide to spread his development across the island, increasing the chance to be impacted by several hazards, but each with more limited impacts.

Access of dwellings to water wells and food markets is taken into account by most players, at the start or during the game, because this allows sparing resources.

Players sensitive to the spatial aspect of hazard distribution are usually also in favor of community initiatives regarding land use planning. Some players inquired about the availability of information about high risk locations and on the possibility to (re-)locate their households to safe places and therefore have a more resilient community. Although this is not directly foreseen in *Hazagora*, such remarks highlight that the game makes players more aware of the need for land use planning and spatial risk assessment. These comments were used as a basis for discussing risk management strategies during the game.

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4.1.3 Cooperative and community strategies

No instructions are given at the beginning of the game regarding the possibilities and modes of interaction between the players. Therefore, players usually start playing individually. Some players quickly understand the benefits of working as a community though. Players with diversified or monopolistic resource incomes develop economic strategies, trading their resources against those from other players to increase their total wealth (Fig. 5b).

Other cooperative strategies were developed, especially to support characters impacted by specific hazards. Donating resources or hosting homeless households of other characters in non-occupied dwellings, for free or in exchange for resources, were observed in several game sessions.

From a community perspective, it appeared generally difficult for all the characters to decide upon, and implement, community strategies. This arises from the fact that players experience different situations in terms of hazard impact and resource availability and develop different perceptions and strategies regarding hazards: the ones pleading for community support often being unable to invest much resources and vice versa. During some sessions, the players decided to collect taxes to be invested in community infrastructures, protection systems, or insurance. The most common community strategy is to either pool resources to be redistributed to hazard victims or buy community protection cards. These strategies are often implemented after several game years and are difficult to sustain throughout the years due to lack of resources of some players. Examples of infrastructures built as a community during the game sessions include a developed road network to connect all the dwellings to water wells and food markets, or refugee camps to shelter for a defined period people that have been affected by a hazard.

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4.1.4 Impact of the strategies on the index of resilience

Looking at the resilience index evolution for a selected game session (Fig. 6), one can see the extreme variance between players. The lumberjack adopted a fast-growth fatalist strategy but has been, in this example, spared. His fast development and his access to resources allowed this character to reach a high index of resilience even though he did not implement additional protection strategies. The guide has been repeatedly affected by geohazards. In year 2, he lost one hut and one household due to ash fall (intensity 3). In year 4, a lava flow burned 3 of his huts and covered 4 of his streets because his infrastructures were clustered in one sector of the island. Households could evacuate thanks to a mitigation card. Due to poor savings, poor access to resources, and little protection strategies, the guide kept a low resilience index throughout the game. A small improvement is observed at the end of the game thanks to the generosity of a player to shelter, for free, one homeless household of the guide. The mayor, in this game session, can be considered as representative of a protectionist player. The development of his community is progressive to insure a good access to resources for all his households. Even though the mayor was affected in year 3 by a tsunami (intensity 1), his savings allowed him to recover from it within 2 years. Cooperation to build a collective road network with another player also influenced his recovery. In the end though, the resilience index for the mayor is lower than for the lumberjack, who did not experience any hazard.

4.2 Disaster comprehension

The survey results demonstrate that, before playing the game, the players already proved to have a moderate to good understanding of most concepts about disasters (Fig. 7). The trend of the answers given by the players at the beginning of the game corresponds to the expectations. Based on the expected answers, it is observed that, overall, 41 % give the same answers before and after the game, 31 % of the players give better answers after the game, while 28 % give less good answers. As specified

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in Fig. 7, and considering the whole population of answers, a statistically significant improvement is observed regarding the players' understanding of the importance of land use spatial planning, community strategies and home adaptation to develop a resilient community. When asked whether settlement location is mainly controlled by the will to avoid hazards, players initially answer negatively but seem to agree more with this statement after the game. For the rest of the statements, no statistically significant improvement is achieved, although the evolution in answers before and after the game follows the expected trend.

Figure 7 also shows that differences in the significance of the change in the answers provided before and after the game are observed for African and European players. Both sets of players seem to be more convinced about the importance of community strategies to decrease a disaster impact after playing the game. On the other hand, after the game, African players tend to be less in agreement with the fact that all hazards do not affect the same places than before the game, which is opposite to the expectations, while European players are clearly more convinced that hazard depends on location after finishing the game. European players also definitively improve their knowledge about the role of livelihood and infrastructure adaptations on decreasing the disasters impacts. Europeans also change their opinion regarding the statement that home settlement is mainly chosen to avoid hazards. Their consideration of the spatial distribution of hazards shows a significant positive evolution.

Based on the answers given to an open question of the survey, it is observed that players realize the benefit of sharing, investing, and helping each other by stating that working as a community can be considered as a DRR strategy. They also indicate the need for a better apprehension of their environment to make adapted choices concerning land use planning and dwellings settlement.

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4.3 Players' impressions

4.3.1 Hazagora as a game

According to the players, *Hazagora* is a fun game to play (Fig. 8). In the questionnaire, people stated that they would recommend the game to others. Some people suggested that the game should be "taught in secondary schools", "available to university staff members so that they can use it to teach students" and "given to the stakeholders to be used during discussions on national policy". According to some players (Fig. 8), the game rules are "the blue-print of real situations", which makes it easier to understand the different steps of the game. Belgian students can less easily relate the processes simulated by the game to their personal experience. However, some people suggested making the game more complex by taking into account the loss of fauna and flora or by incorporating more livelihood diversity. The flexibility of the game, enabling players to define their own strategies is highly appreciated (Fig. 8). Finally, the tempo of the game is considered as reasonable by the players.

4.3.2 Hazagora as a tool for raising awareness on risk and disaster risk reduction strategies

Players indicated that they receive enough scientific information throughout the game to have a better understanding about the physical mechanisms of the hazards and their impacts on human properties and livelihood, with a clear focus on the latter (Fig. 8). They also state that *Hazagora* allows them to generate discussion in the group and collect information that may help them in developing mitigation plans in their personal or professional life.

A distinction though has to be made between the evaluation of the game by African and Belgian players due to differences in life experiences and geological situations (Fig. 8). Where African players highlight the usefulness of the game to develop mit-

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igation plans at a personal and a professional level, European players mostly draw attention to the scientific information conveyed by the game.

5 Discussion

5.1 The strategies

Comparisons could be made between development and DRR strategies implemented by the players and case studies of human communities confronted to disasters as described in the literature (Wisner et al., 2003). We here limit ourselves to a conceptual interpretation of the *Hazagora* strategies based on an analogy with a theory from ecology. The fast-growth fatalist and protectionist strategies developed during the surveyed sessions are comparable to the *r* and *K* strategies described in ecology for the establishment and development of species in nature.

The *r* strategy is adopted by species living in a disturbed or newly created environment (Brown and Lomolino, 1998). These species are pre-adapted to colonize such environment thanks to their broad ecological tolerances and the fact that species adopting *r* strategies have a large number of offspring at an early age (Brown and Lomolino, 1998; Parry, 1981). All the resources are spent for reproduction. Generation time is short mainly because of lack of parental care (Parry, 1981). This strategy can be compared to the fast-growth fatalist strategy adopted by some *Hazagora* players. In a hazardous environment, players develop rapidly their households. All the resources are spent to their development without adopting DRR strategies. Those players bet on the chance to be spared by hazards and evaluate that the relative impacts of a hazard will be lower on an extensive community, despite the higher chance to incur fatalities due to hazard impacts.

In nature, species adopting the *K* strategy are living in a more stable environment which is approaching its carrying capacity. They are therefore more adapted to efficiently use the limited resources (Brown and Lomolino, 1998). *K* strategy species have

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a delayed reproduction with a limited number of offspring but of higher-quality (Brown and Lomolino, 1998; Parry, 1981). Small amounts of resources are spent on reproduction but the life expectancy is longer thanks to parental care. Selection is due to resource shortage (Parry, 1981). *Hazagora* players adopting protectionist strategies during the game are comparable to the K strategy species. They aim at an efficient and sustainable management of their resources in order to develop themselves progressively. Savings are made and a large diversity of protection cards is collected to allow households overcoming disasters. Diversification of the income is also proposed by the players to protect themselves as multiple income source is an effective resilience strategy (Mavhura et al., 2013). In extreme situations, households will be sacrificed mainly due to lack of resources.

All fast-growth fatalist, protectionist, spatial, individual or collective strategies described above were observed once or repetitively during the surveyed sessions but their implementation depends on various factors. Real life experience and impacts experienced during the game may influence the players' strategies. These people usually adopt more protectionist strategies with a good access to resources. Observations also show that the strategy of a player changes during the game. Even if a player chooses for specific strategy during the game, he usually ends it with an extreme fast-growth fatalist strategy. At the end of the game, players have nothing to lose and invest all their savings to develop. Although it is initially stated that the cooperative goal of the game is to reach a resilient community as a whole, each player might favor the development of their own character, influencing therefore his decisions. In addition, power relationships and social skills also seem to influence the group decisions. The game attributes a leadership position to the mayor during the discussions. This character is often caricatured and suffers sometimes from exclusion. In particular, African players project on the mayor their lack of trust regarding the authorities of their own country. Of course, *Hazagora* does not represent a real political system and the associated power relationships, but these observations highlight that the trust and cohesion between stakeholders and population are essential in the decision process. Experience

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shows that the personality of the player is influential. Charismatic or talkative players will more easily be able to impose their strategy even if it does not contribute to the community objective, whereas shyer players might not be able to defend their arguments. Game sessions with existing group cohesion were more animated. *Hazagora* hence also trains important social and negotiation skills.

5.2 Hazagora as a game

Hazagora has been developed with the aim to encourage co-learning through players' interactions and was therefore designed as a board game. In our view, the discussions between people who would not sit down together or interact otherwise if using traditional teaching methods, lead to a better sharing of knowledge and experience. Besides, in several countries where the game has been tested, internet connection and computer facilities are limited and a board game appeared thus as an appropriate tool. But is the game attractive and are the objectives met?

The appreciation of a game is something highly personal and players have different interests in what they are looking for. However, some ingredients are important to make a game attractive: (1) It has to be playful and nourish the desire to play it over again (Annetta et al., 2014; Castella et al., 2005; Turkay and Adinolf, 2012), (2) The rules have to be coherent to the target audience and should be easy to understand (i.e. rules should have a logic similar to reality) (Dieleman and Huisingh, 2006; Souchère et al., 2010), (3) Players need tension, they have to be surprised and be challenged without having to waiting too long (Martin et al., 2011; Turkay and Adinolf, 2012), (4) The graphic of the game has to be appealing and should help the player to relate the game to real situations, since it is the first contact of players with the game (Martin et al., 2011).

Based on the survey, *Hazagora* appears to be positively evaluated on each of these different characteristics. The game is appreciated by the players, who would generally recommend it to others. The rules are easy to understand, even though African players required more time before fully understanding the game structure, as board games are

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less part of their culture. The alarm defining when a hazard happens generates some tension and introduces an element of surprise to the players. Because hazards are implemented on the board game, players are challenged to protect their households and belongings. Discussions that occur during the game slow down the players who want to pursue the development of their households and protection measures. Discussions are however essential as it is during these moments that knowledge and experience are shared, community actions are debated and information is formalized by the game master. The drawback is that one game session takes at least 3 h, in order for the players to experience sufficient hazard situations and test DRR strategies to fully benefit from the game learning potential. Finally, the design and the quality of the game illustrations and pawn are also helping the players to appreciate the game. Specific attention was paid to create characters and visuals that are generic enough in order for players from different cultures to be able to connect to them (i.e. faces and livelihoods of characters).

5.3 Hazagora as a tool for raising awareness on risk and disaster risk reduction strategies

Several games have already been developed to raise awareness about one or several hazards and reduce their impact (e.g. "*Stop disasters!*" – UN/ISDR, "*Disaster Hero*" – FEMA, "*Riskland*" – UN/ISDR, "*Save Natalie!*" – IDNDR, "*Paré pas paré*" – Croix-Rouge française) (Croix-rouge française, 2012; FEMA, n.d.; International Decade for Natural Disaster Reduction, n.d.; UN/ISDR, 2004, n.d.). These DRR-games target preferentially a young audience as children are known to be a vulnerable group (Elangovan and Kasi, 2015; UN/ISDR, n.d.). Once educated about DRR, children are considered to be contributing more than adults to a change towards a more proactive preventive approach to disasters (Johnson et al., 2014). These games can be played as a board game or online. Online games allow giving systematic scientific information to the players but limit the interaction between them. It also has to be noticed that these games

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do not emphasize the aspects of livelihoods and access-to-resources. They are more focusing on basic protective measures for hazards.

Hazagora targets an older audience, as we argue that serious gaming is a useful communication mode for teenagers and adults, especially for addressing complex processes and for favoring interaction. The game has been tested with groups of different age, culture, knowledge and experience. The players' feedbacks on the game were always positive.

Information about the hazard mechanisms and their impacts on infrastructures, natural resources and livelihood are illustrated during the game. African players suggested that the scientific information provided during the game is sufficient but their appreciation for this aspect is always lower than for the European players. This may be due to a difference in initial knowledge. They have more experience with geohazards and that is why they want to learn even more about the hazards they might face in their daily life, resulting in higher expectations. This highlights the need to adapt the focus of the game, especially the discussions and the explanations provided by the game master, to the background of the players.

Hazagora aims at illustrating the four elements of the risk equation, i.e. hazards, spatial exposure, vulnerability and DRR capacities. Throughout the game, importance is specifically given to the influence of livelihoods, access-to-resources and contrasted DRR strategies, as these concepts are typically less familiar to the players. Even though not all answers to the questionnaires demonstrate a significant improvement in knowledge and understanding about disasters, and how to reduce the risks involved, the game generally contributes to increasing the players' awareness regarding different factors influencing risk and the need to interact to test new strategies. Results showed more significant improvement among European players. On the other hand, the game generated more intense discussions about contrasted DRR strategies among African players. This can be explained by the fact that those players are better acquainted with at least one of the hazards described in *Hazagora*, that they were mostly older than the European players and that they realize more that the discussions on new strate-

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gies to implement on the board game can be useful to develop their own mitigation plans at a personal or at a professional level. These results highlight that *Hazagora* has the potential to be used for different but complementary purposes, focusing on educating about geohazards and risk concepts, or as a basis to generate discussion on identifying and testing possible DRR strategies, depending on the target audience.

For some participants, the surveys indicated an evolution opposite to the expectations. This can partially be attributed to the way some of the statements were formulated, and to the difficulty of isolating one factor from the other ones. Answers to the questionnaires also depend on the specificity of the game session. Indeed, each game session is unique: hazards experienced, discussions and extent of the impacts on the board game will differ, which may result in more attention being given to one or another disaster factor. The game master has to ensure that discussions address all elements influencing the disaster and that enough time is allocated to summarize the main message of the game in the end. In order to be sure that players receive all the information needed, information sheets about the hazards and adapted DRR strategies developed during the game are distributed to each player after the game.

5.4 Limitations and perspectives of the game

One of the key limitations of games is the need for significant simplification and generalization. The former insures that a game is fun to play and that the rules are understandable. In terms of hazards, only four geohazards are addressed by *Hazagora.* In order to maximize the learning outcome of the game and let players experience different hazards of contrasted magnitude, it is advisable to implement adaptations such that a hazard of a given magnitude that already has been experienced in the game does not take place again in the following years. The hazard spatial extent is also simplified, neglecting for example the topographic control on lava flow and tsunami distribution, as well as the variation of ash fallout or earthquake intensity with distance from the source. Although hazard intensities are differentiated, the game does not represent a realistic magnitude – frequency distribution nor considers the spatial variation of the

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probability of hazard occurrence. Impacts of the hazards on the island are also limited to the elements present on the board game. Only infrastructural, financial and human losses are therefore taken into account. Cultural, economic, environmental and political factors influencing the livelihood strategies, the access to resources and the decision process are not represented. The livelihood profiles of the characters are also imposed and do not evolve during the game.

The game is also very generic in terms of geographic setting and character profiles. This has the advantage that it can be played with participants of different age, culture and with different knowledge about natural risks and risk management. However it might prevent some players to directly relate to the game and to represent the specific hazard and risk conditions of their environment they are familiar with. These issues of simplification and generalization can partially be addressed by the game master by providing information and examples relevant to the players, and by inviting the players to discuss and possibly adapt the game rules. As already mentioned above, more detailed information on hazard mechanisms, spatial distribution of hazards and impacts are provided to each player in an info leaflet at the end of the game. In the future, modified versions of the game in terms of geographic setting, but also resource distribution or accessibility could be implemented to fit the needs of a specific region and target audience. Finally, implementation of additional or alternative hazards, such as landslides or flooding, could be considered if topographic characteristics of the landscape are properly simulated on the board game. Rules would stay more or less the same but a new set of impacts provoked by the hazards would have to be defined.

Another limitation of the game, especially for improving DRR awareness, is the time required to play it. The need to dedicate several hours to a game session is clearly a limitation for integrating of the game into a teaching program and can only be offered as an extra-curricular activity. A balance has to be found between the play and the informative aspect of the game. Because of the diversity of the game objectives, it may be beneficial to play the game several times. During a first session, time could be dedicated to explain the rules and to discover all information needed to get a better

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understanding of geohazards. In a second session, the game could then focus on highlighting the factors controlling the disasters, while a third session could focus more on the interaction between the players as well as on developing and testing DRR strategies.

A final limitation of the game is the need for a game master highly knowledgeable in the addressed topics to lead the game and guide the players' discussions. The game sessions were so far led by one of the co-authors, but to multiply the impact of the game, there is a need in the future to train teachers or other science communication actors as game masters. A detailed game master guideline document is already available to describe the game procedure, key points to be highlighted during the discussions, and some examples of recent disasters to use as an example.

Based on the experience of the *Hazagora* sessions and the results of the survey, we do not argue that this learning method can replace more traditional and structured teaching methods, but rather that it serves as a useful way to activate participants and introduce them to the complex concepts of disasters.

6 Conclusions

In this paper we presented a new approach using a serious game to educate a broad audience about geohazards, disasters and DRR strategies, including secondary school students, citizens and risk managers.

Hazagora demonstrated to be a successful board game that players find fun to play, informative and stimulating. Despite the necessary simplifications, the game provides a good representation of the main elements of natural disasters. The game challenges the players to protect their households against unforeseen geohazards. The game format facilitates the learning process, enhances discussions between players and encourages them to test new DRR strategies.

Hazagora has been tested with young and older player groups from different backgrounds, residing in Europe and Africa. The survey demonstrates that most players

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already had some understanding about disasters before the game but that their knowledge tended to improve after the game. The objectives achieved depend on the targeted public. For people with little knowledge about geohazards or disasters, *Hazagora* mainly manages to improve their understanding of geohazards and the factors controlling a disaster. For people confronted in their daily life with geohazards, the game is mainly able to generate discussions which may help in developing risk management strategies. The game impact is expected to improve if it is played several times by the same players, who could then improve their resilience strategies. Experience shows that players not used to play board games need more time to understand the game rules. In the future, new versions of the game may be implemented to adapt the set up to specific places, hazards or targeted audiences.

To conclude, *Hazagora* has been shown to contribute to making players more aware (1) about hazards mechanisms, their intensity, spatial extent and impacts on infrastructures, natural resources, and livelihood, (2) about the elements influencing the vulnerability of a community with respect to hazards, (3) about potential strategies that can be applied to make a community more resilient. Indeed, new DRR strategies can be implemented in the game which allows players to test various risk management approaches without having to deal with the real consequences of their decisions. The game is therefore a new relevant alternative among the many tools and methods that have already been proposed for raising awareness on disaster risk reduction.

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the GeoRisCA project '*Geo-risk in Central Africa: integrating multi-hazards and vulnerability to support risk management*' funded by the Belgian Science Policy (BELSPO project SD/RI/02A).

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Table 1. Game session information.

Country	Number of game sessions	Number of participants	Participants' profile
Belgium, Brussels	4	21	Secondary (16–18 yr) and university students
Comoros Islands, Moroni	3	22	University students, citizens and stakeholders
The DRC, Bukavu	1	14	University students
Tanzania, Dodoma	2	18	Earth scientists and risk managers

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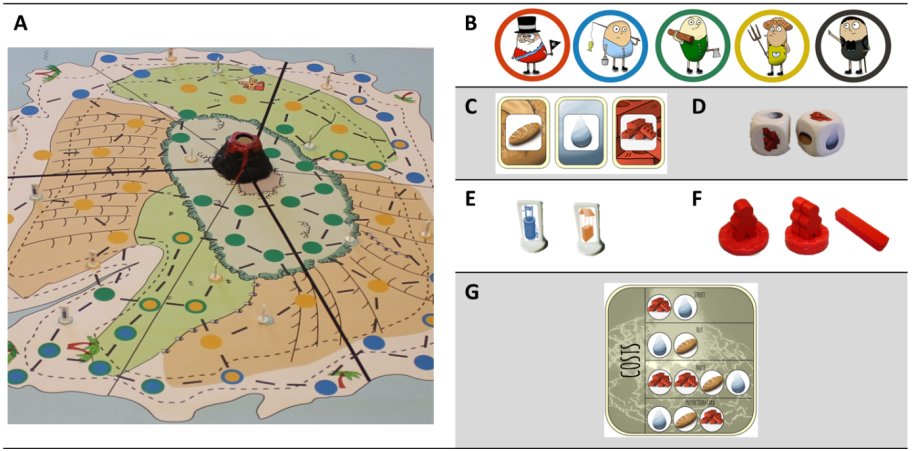

Figure 1. Set up of the game: **(a)** board game; **(b)** character cards with from left to right the mayor, the fisherman, the lumberjack, the farmer and the tourist guide; **(c)** resource cards: bread, water and bricks; **(d)** resource dices; **(e)** water well and food market; **(f)** hut (one family), house (two families), and road; **(g)** cost information card to build new streets, huts, houses and buy protection cards.

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Figure 2. Huts (one household) and a house (two households) having access to a water well (blue and red characters) and a food market (yellow and green characters) by road. This allows freely benefiting from these resources.

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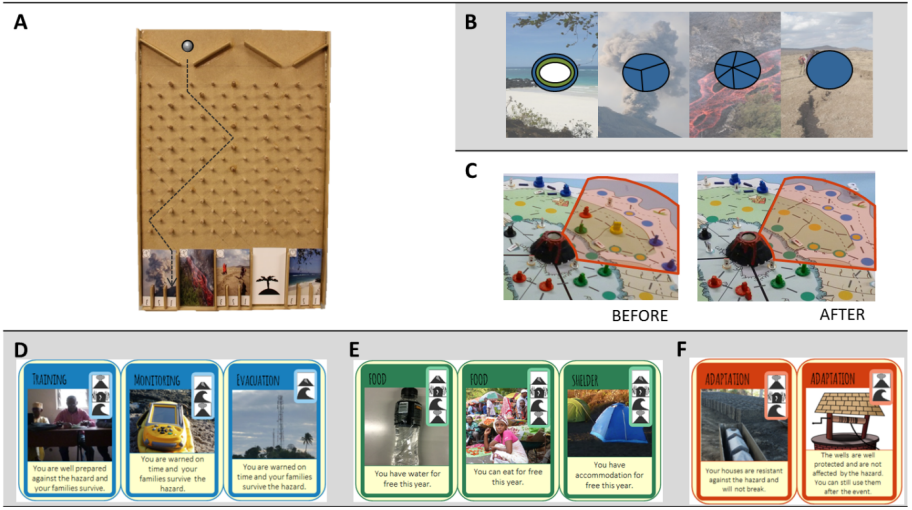

Figure 3. Defining the hazard: **(a)** probability tree; **(b)** spatial extent of tsunami, ash fall, lava flow and earthquake on the island; **(c)** impact of a lava flow on the board game; **(d)** mitigation cards; **(e)** preparedness cards; **(f)** adaptation cards.

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Figure 4. Potential hazard impacts if players are not protected. Impacts will be different for different hazard intensities. A cross over an infrastructure means its destruction within the affected zone. A cross over a family indicates that the families living in the affected zone will not survive the hazard. Characters with a small cross suffer a loss of income for one year.

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Figure 5. (a) Game session organized with citizens in Moroni (Comoros Islands). **(b)** Interaction between Belgian students to develop a resilient community.

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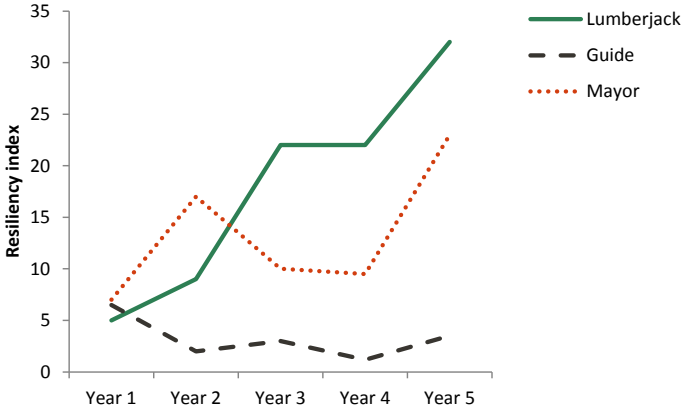

Figure 6. Example of the evolution of the resilience index for fast-growth fatalist players not affected (lumberjack) and affected (guide) by geohazards during the game and for a protectionist player (mayor) affected but well prepared.

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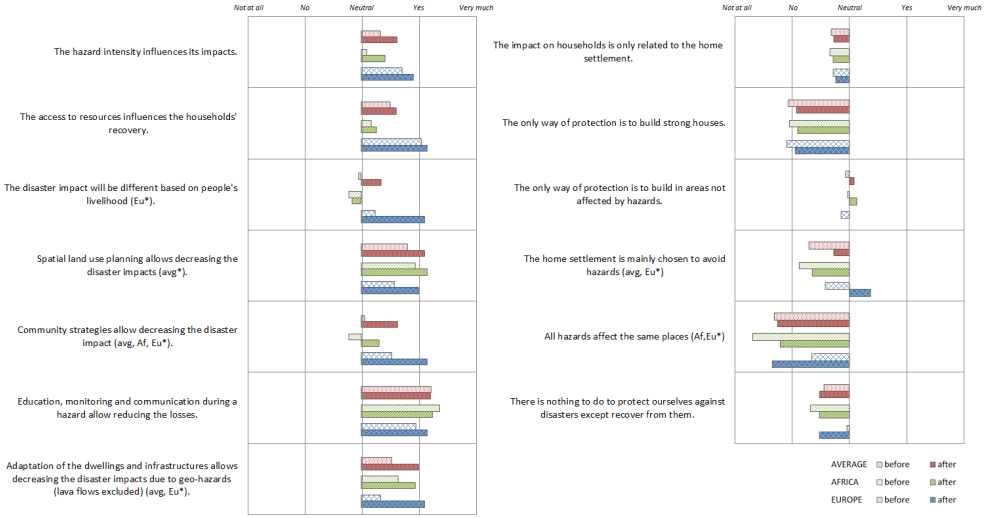

Figure 7. Evolution of the players' (n = 56) understanding about the different factors controlling the impact of a disaster before and after the game. avg* – evolution significantly different on average ($p < 0.05$); Eu* – evolution significantly different for European players ($p < 0.05$); Af* – evolution significantly different for African players ($p < 0.05$).

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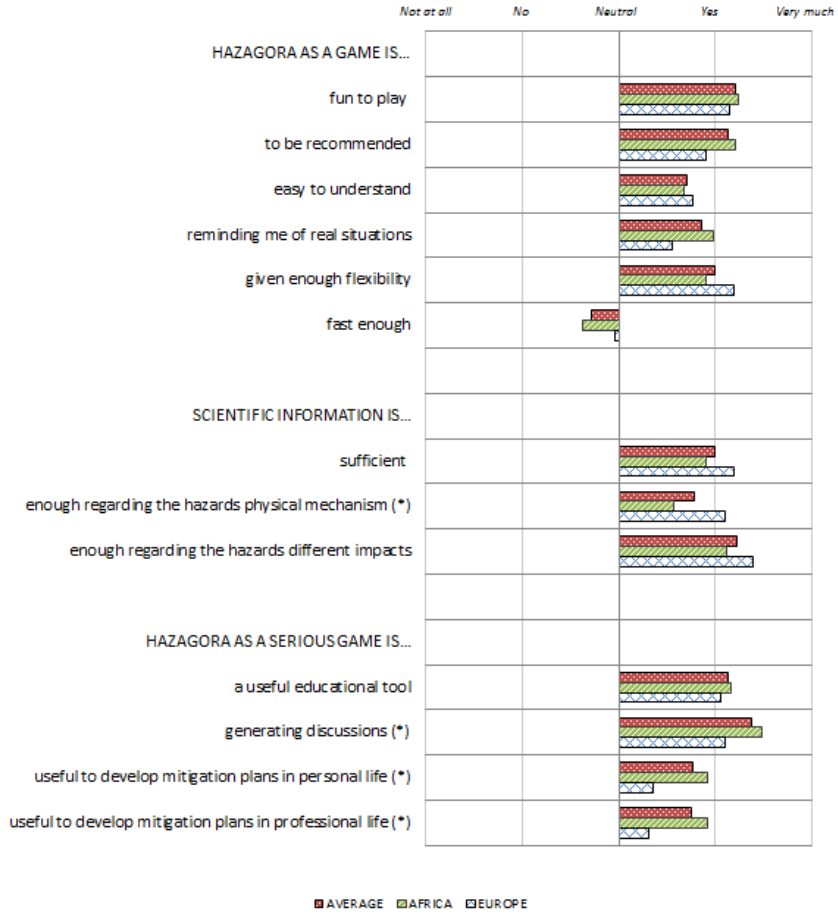

Figure 8. Appreciation of the game by the players ($n = 75$). (*) Results are significantly different between European and African players ($p < 0.05$).

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