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Improving Intuitive Reasoning Through Assistance Strategies in a Virtual Reality Game

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Abstract

Intuitive reasoning relies on intuition, experience and affective judgment in order to resolve problems and acquire knowledge. This form of intelligence, based on unconscious learning, provides fast access to knowledge and is most of the time filled from learning by experience. Virtual Reality (VR) is a way to offer environments in which a user can deploy intuitive reasoning and acquire knowledge faster than usual academic training. In this paper, we use Inertia, a VR game that we have designed to teach some basic physics rules. We assess emotional behavior of the participants considering their engagement or frustration in the game, through electroencephalograms. Assistance strategies are integrated into the game to provide help according to the emotional measures. Inertia is composed of four types of games (Bowling 1, Bowling 2, Pivot, and Billiard) available on two versions (V0: without assistance strategies and V1: with assistance strategies). According to the data collected from the two versions, we noticed that assistance strategies could improve participants' performance of more than 50% for some games (more precisely Billiard). The impact appeared not only in terms of reducing the number of failures, increasing the number of success, but also increasing the scores in all categories of the game.

Introduction

Nowadays, we can consider different kinds of reasoning such as inductive reasoning, deductive reasoning, comparative reasoning, example reasoning, clinical reasoning, intuitive reasoning, to mention just some of them. In this paper, we are concerned by intuitive reasoning which consists of instinctive and unconscious knowing without deduction or logical reasoning. Intuition itself is defined as the power of obtaining knowledge that cannot be acquired either by inference, observation, logical reasoning or calculation. However, this knowledge could be acquired through experience, associative learning and information stored in long-term memory (Betsch 2007). People who use intuitive reasoning rely on instant responses including affective valences, which are reached with little apparent effort. We can therefore deduce that intuitive reasoning is based on spontaneous judgment or decision which relies on practice and experience stored in long-term memory rather than logical and analytic reasoning (Kolb 1984).

Intuitive reasoning has many benefits. For example, intuition can greatly enhance the effectiveness of the decision making. It's also fast and theory free. It relies only on practice. Whereas, we should note that intuition does not provide accurate predictions of the problem like analytic reasoning. To summarize, using either intuitive reasoning or logical reasoning have some advantages and disadvantages. So, choosing which reasoning is most suitable relies on the nature of the problem and the resources provided to solve it.

As we said above **intuitive reasoning** can emerge from subconscious state. One of the advantages of VR, compared to other interactive environments, is that the user is isolated from external distractions and this condition allows better access to the subconscious. Immersion in VR can trick the subconscious mind of the user, so that he believes he is in a real word. As intuition is an automatic non-conscious process (Frankish 2010), it resides in the subconscious mind. So, using a VR environment is a way to favor and develop intuitive reasoning. VR allows to trigger intuitive interpretation of the situation with actions or decisions emerging from the common sense and this is a very interesting channel for strengthening reasoning and more generally learning. In addition, if we combine VR environment with a game, which can increase engagement and motivation of the user, we improve his/her capability of knowledge acquisition. With this goal in mind we designed **Inertia**, a VR game intended to teach basic physics rules to : 1) provide a learning environment able to trigger intuitive reasoning, and 2) to test assistance strategies able to help the learner according to his cognitive state.

Mental assessment. To evaluate the reasoning state of the learner we focus on two mental states: *engagement* (the learner is fully involved and interested in the reasoning), and *frustration* condition (the learner is lost and does not find the solution). These mental states are analyzed using electroencephalograms.

Assistance strategies can be defined as strategies to help the learner to reason correctly and progress in the knowledge acquisition. To help him, we focus on three types of *solutions* and two types of *messages* according to the learner's mental state and his success or failure in each exercise. The strategies are grouped into: complement of solution using a suggestion provided to the learner in order to help him find the solution (Green et al. 2012), part of solution using some elements of the solution, and solution with the whole solution so that he can reach the next level of the game. Messages are decomposed into: messages of encouragement to encourage the learner to continue playing, and messages designed to calm the learner and decrease his frustration.

The paper is organized as follows. In section 2 we talk about how to improve intuitive reasoning. Section 3 describes the VR environment and the main characteristics of the game. Section 4 describes the principles of the assistance strategies. In section 5 we present the experiment which led to the results presented and discussed in Section 6.

Improving intuitive reasoning

Intuitive reasoning. As we mentioned before, intuitive reasoning relies on intuition, experience and affective decision used to resolve problems. Intuition is also known as a form of unconscious intelligence (Gigerenzer 2007, Kruglanski et al. 2011), very different from logical and analytic reasoning which are based on calculation. It's rather based on affective and unconsciousness behaviors. We can see this type of intuition while practicing sports, shopping, choosing friends, etc. We also consider that this behavior occurs when *playing games*. Games and particularly serious games (SG) are tools that can be used to enhance learning (Dunwell et al. 2012). We believe that one method to enhance intuitive reasoning is first to choose games able to trigger this type or reasoning, and particularly VR games.

Virtual Reality Games. Games and applications could be presented to the player according to a variety of forms. It could be presented on a normal computer monitor, smartphone screen, 3D computer monitors which work with 3D glasses, etc. However, the most immersive way to present a video game to the player is VR. With this technology, the player don't see anything that could disturb him except the virtual world (he is not solicited by external factors). VR immersion tricks the mind of the player, so he thinks that he is really inside the game and he acts like in normal life. This immersion is driven especially by the subconscious mind of the player, so his reactions will be based more on his intuition than on his logic. Thus, the first advantage of VR is the immersion which could be useful for both the conscious and subconscious mind. The user can focus more, learn faster, and think better, since he is isolated in the VR world. The immersion is even more efficient to the subconscious mind because it lets the user learn by experience and use his intuition to succeed and find the solution.

VR can be used and can be useful in several domains such as Education (Pan et al. 2006, Merchant et al. 2014, Ott et Freina 2015), Social life (Freeman et al. 2014, Didehbani et al. 2016, Ip et al. 2016), Medicine and health (Miller el al. 2013, Price et al. 2014, Didehbani et al. 2016), and Neuroscience (Frankish 2010, Bohil et al. 2011, Yates et al. 2016). In education domain, (Ott and Freina 2015) show that the immersive property of VR offers many advantages and allows the students to feel objects and events that are not physically reachable.

In neuroscience domain, Bohil and his team show that VR is useful for neurosurgery and cognitive assessment. In fact he mentions that "*VR allows naturalistic interactive behaviors to take place while brain activity is monitored via imaging or direct recording* (Bohil et al. 2011)."

Thus, intuitive simulation is a powerful approach to problem solving situations. This is particularly useful in 3D environments where the result of an action depends on position, force to apply, resistance of elements and physical factors. For all these reasons we have developed the Inertia game, which is described in the next section.

Assistance strategies. With such an environment able to trigger intuitive reasoning, assistance strategies can then be used to facilitate teaching and to progress more effectively in the game (McNamara et al. 2010, Ghali et al., 2016). For instance, McNamara et al. described five main characteristics that describe SG as game based features. Game based features aim to motivate learners and increase their playful aspect. However, Ghali et al. (2016) mention that one problem of SG is that they concentrate more on playful aspect and don't focus on educational aspect. In order to solve this problem, the authors proposed real time models for providing learners with help if necessary. Their models used machine learning techniques and predicted the need of help with the accuracy of 54.1%. The prediction was based on a collection of physiological data (electroencephalography, eye tracking and emotional recognition). The authors showed that it is possible to build reliable machine model classification of three states: (1) no help required, (2) medium help required, and (3) strong help required. Instead of using only messages of help, we propose in this paper to introduce also assistance strategies that are composed of three types of help: (1) complementary of solution (Green et al. 2012), (2) part of solution, and (3) whole solution. We suppose that introducing these strategies in our SG will be a second method to improve intuitive reasoning and then enhance learning.

As proposed by Ghergulescu (Ghergulescu 2014), the use of EEG indices of mental states is effective and can produce reliable results. In order to guide our instructions of assistance strategies, we propose to extract two mental states from electroencephalograms: (1) **engagement** that gives a clue of learner's attention and concentration while learning, and (2) **frustration** that gives a clue if the learner is bored and/or not interested in the content. We choose these two mental states because they give us an indication of the whole mental state of a learner and if he/she is progressing in reasoning or stacked. According to the evolution of these two mental states, we generate our assistance strategies in order to provide learners with an adequate help.

Inertia: a Virtual Reality Game for Learning Dynamic Rules

In order to monitor the mental state of the learner and test our assistance strategies, we created a game called Inertia. Inertia is based on the principle of force transformation and quantity of movement, known in physics of dynamics. For example, what force and direction should we apply to a billiard ball in order to reach a specific target? We created a platform of several games (3 games: Bowling, Pivot, and Billiard, and 4 levels: Bowling 1, Bowling 2, Pivot, and Billiard) using Unity 5.3.1 which contains a built-in physics engine able to handle a simulation of dynamics.

Inertia was optimized in order to run and react quickly in a VR mobile headset (Samsung Gear VR headset). The player can control the game with a bluetooth game-pad, and with the rotation of his head he can see the VR environment in 360 degrees. In this way the learner is immersed into an intuitive environment in which rules to apply come from the subconscious (sometimes called rules of thumb).

In order to cover a variety of physics rules, we built three categories of games in Inertia: Bowling, Pivot and Billiard. For the Bowling, we made two difficulty levels and just one for the other games. For each game, the player has five attempts to play and the score appears after each attempt. A help message is displayed after every trial, and its content depends both on the failure or success and on his mental state as explained in the previous section.

The score of each game is calculated as follows: for Bowling, the score depends of the number of pins that the ball hits, it varies between 0 and 10 pins. The success is considered if the player shoots 5 pins (50%). Whereas, the score of Pivot game depends only on the success or failure. If he succeeds, he gets 100%, else he gets 0%. The success in this game is considered if he can get the red ball into a bucket. Similarly, the score of Billiard depends only on the success or failure. If he succeeds, he gets 100%, else he gets 0%. For this game, the success is considered if the player can drop the coin which is situated on the orange ball inside the black circle. Some screenshots of each game developed in Inertia are presented in Figure 1, together with a description of the difficulty to overcome.

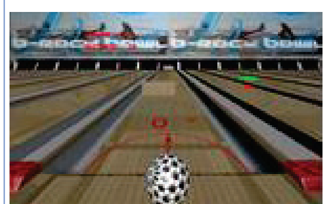
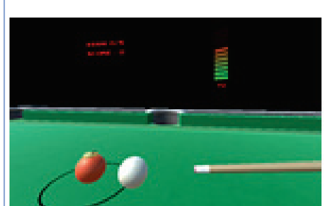
Screenshot	Description
	**Bowling1:** in this difficulty level, we put an obstacle in the middle of the track. The player should choose the right angle and thrust, so that the ball can pass the obstacle and reach the pins.
	**Bowling2:** in this difficulty level, we changed the type of ball to a soccer ball, so that the player has to consider the bounce of the ball and find the right angle and thrust as in Bowling1.
	**Pivot:** in this game, we placed two tilting wooden beams initially in equilibrium. A black metal ball fells onto one beam and inclines more or less the beam which hits the other beam. The player has to choose the mass of the black metal ball in order to tilt the wooden beams and let the red ball fall inside the bucket.
	**Billiard:** in this game, a balanced coin is placed on the orange ball. The player has to apply the right thrust to hit the white ball in order to drop the coin inside the black circle.

Figure 1. *Details of Inertia*

Assistance Strategies in Inertia

The principle of assistance strategies is based on two types of messages (ME, MC) and three types of solutions (SO1, SO2 and SO3) which are sent to the learner according to their mental state and result:

- ME: presents a message in order to encourage the player to progress in the game,
- MC: presents a message in order to calm the student and decrease his state of frustration,
- SO1: complement of solution that tries to present the adequate message according the learner's choice of parameters of the game,
- SO2: part of solution that gives exactly one parameter of the game,
- SO3: whole solution given to the learner in order to let him progress in the game.

These messages and solutions vary according to two mental states: frustration and engagement, extracted from Electroencephalograms, and two evaluation metrics: success or failure in each game. An overview of the distribution of these strategies is presented in Figure 2.

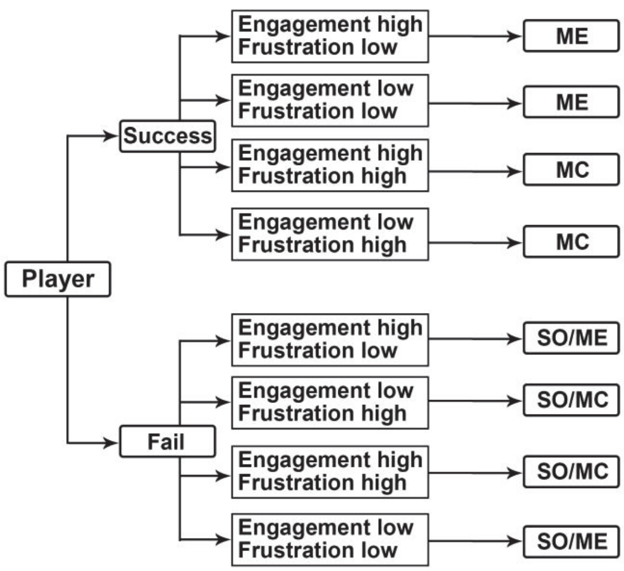


Figure 2. An overview of the distribution of messages and solutions in Inertia

This distribution also varies according to each trial of a level. For example, for the best game bowling, the player can try maximum five times. If he successes, we normally generate a message (ME or MC). However, if he fails we present in this case the solutions with the corresponding messages. Table 1 gives an example of assistance strategies integrated into a game (more specifically in the bowling game).

Table 1. Examples of strategies in bowling 2 game

Messages and Solutions	Examples
ME: E high, F low, Success	Well done! You are a good player! Continue like this.
MC: E Low, F low, Failure	Don't worry, try to play again. Be careful, your behavior seems to be disengaged, so try to be more concentrated and more engaged
SO1: complement of solution	If Speed>Speed$_{Optimal}$: your speed is too high. You must apply less power
SO2: part of solution	Okay, we will help you. Let's choose an angle between 5 and 10 degrees
SO3: whole solution	The right angle is 7 and the right power is 90

Experiment

In order to study the effectiveness of assistance strategies, we built two versions of Inertia: V0, a version without assistance strategies, and V1, a version including assistance strategies. The two versions were experimented on 30 participants from University of Montreal (11 female and 19 male, mean age 28.76). Before starting the experiment, the participant signs an ethic form that explains the study and mentions its advantages and disadvantages. In the experiment, the participant is equipped first with the Emotiv EPOC headset (see Figure 3) in order to extract the two mental states: frustration and engagement. These states are used further to generate the assistance strategies.

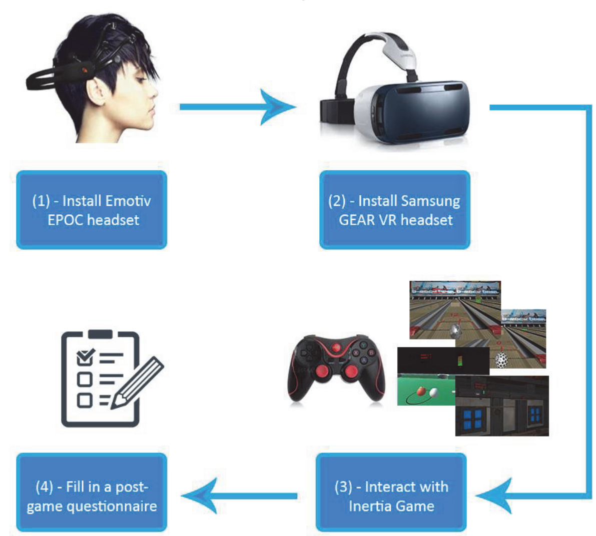


Figure 3. The experimental process

In the second step, we set up the game into a galaxy 6 smart phone which is placed in the headset GEAR VR and install this headset on the participant.

After these steps, the participant could manipulate the 3D environment and practice his skills with Inertia game described above. Finally, we ask the participant to fill in a post-game questionnaire. This questionnaire is used to collect demographic information from the participants as well as their need of help in each section of the game.

Results and Discussions

To compare the two versions of Inertia, we calculated in each version the number of failure and success as well as the scores' variation, grouped by the type of game. The two following figures show the variation of the number of failure and success in each type of game. Figure 4 gives statistics on Inertia V0 in terms of the number of failure and success, whereas Figure 5 illustrates the same statistics on inertia V1 with assistance strategies.

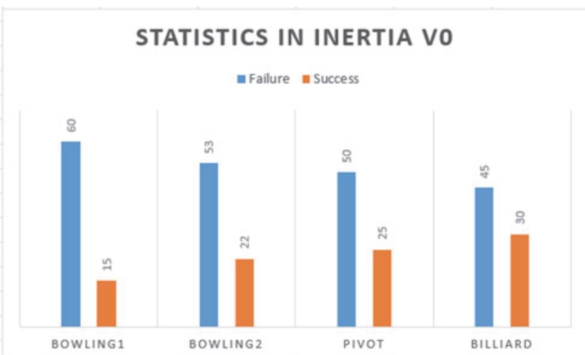


Figure 4. Descriptive Results in Inertia V0

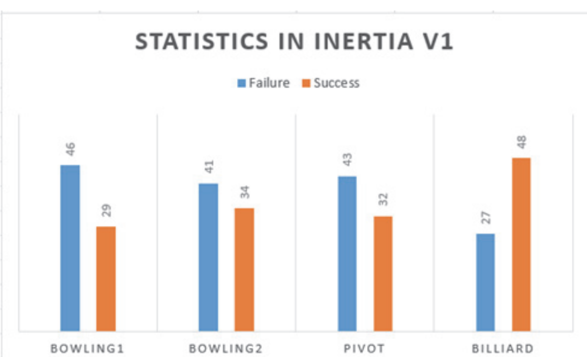


Figure 5. Descriptive Results in Inertia V1

From Figure 4 and Figure 5, we can notice clearly that the Bowling is the hardest game with a maximum of failure in both versions (60% vs 46%). Moreover, we can see clearly that the assistance strategies added to Inertia V1 have a strong impact on reducing the number of failures and increasing the number of success in all the games.

From Figure 5, we also notice that the success in Billiard game increased significantly and the failure was reduced by quite half (45% vs 27%). This means that assistance strategies were specifically more successful in this game. To prove this result, we also conducted descriptive results on scores and run a t-test that will be described later.

For the descriptive results, we calculate for Inertia V0 and V1 the average of scores for all the participants, as well as the standard deviation (SD), minimum (Min) and maximum (Max). These results are presented respectively in tables 2 and 3. It should be noted that all the scores for all the games are normalized between 0 and 100.

Table 1. Descriptive statistics of scores in Inertia V0

Game	Mean	SD	Min	Max
Bowling1	16.8	17.42	0	46
Bowling2	28.53	17.06	0	62
Pivot	33.33	16.19	0	60
Billiard	40	16.19	20	80

From table 2, we confirm our finding that the Billiard is the easiest game for most of the participants because it has the highest score's average (40%). However the Bowling1 remains the most difficult one (16.8%). This can be explained by the fact that a success in a bowling needs that a player shoots more than five pins out of 10 in only one trial.

Table 2. Descriptive Statistics of scores in Inertia V1

Game	Mean	SD	Min	Max
Bowling1	33.5	20.12	15	52
Bowling2	41.73	19.73	28	68
Pivot	42.66	23.83	0	80
Billiard	64	22.59	20	80

From table 3, we see clearly that for **all the games** the mean score is higher in Inertia V1 compared to Inertia V0. This result could be explained by the impact of assistance strategies and their role to guide the players in almost all the games. The assistance strategies can improve learners' reasoning and let them progressing faster in the game.

Finally, to confirm that hypothesis and to study the scores' improvement in Inertia V1, an independent-samples t-test was conducted to compare scores for games in both versions. There was a significant difference in the scores for V0 (M=29.66, SD=18.27) and V1 (M=47.4, SD=23.62) conditions; t(59)=5.09, p = 0.00**<1%. These results are very significant and show clearly the difference between the two versions of the game. Moreover, we calculated the effect size (a Cohen'd of 0.84) which is large. This proves that there is an improvement in overall learners' scores. We also conducted an analysis of variance ANOVA to see if the games are statistically different. Results considering four types of games (independent variables) are also very significant (F(3.86)=10.98, p=0.00**) showing that the design of the games is different. Despite this difference in the games' design, the assistance strategies proposed play an important role in enhancing learning.

Conclusions

In this paper, we studied the importance of adding assistance strategies in an intuitive reasoning VR game. We conducted an experiment and tests. Results showed that for all the games, learners' performance increased when adding assistance strategies, both taking in consideration the global score and the number of failure and success. This can be a useful finding for improving the training in intuitive situations such as physical interventions in many domains (sport, surgery, and marketing) where the decision is based on intuitive behavior and contributes to learning by experience. Future work will aim to experiment more strategies on the Inertia platform.

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