THE ROLE OF MOTION INTERACTION IN LEARNING
MATHEMATICAL TASKS IN A COMPUTER GAME

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Abstract
New technologies have long demonstrated great potential as tool to provide competence stimulation and to complement educational programs. In the game “Matemáquina do Tempo” we implemented an environment where children interact with the world using their own motion patterns to train mathematical competences. In the work we present here, there was motor interaction with the digital game in a counting and grouping task. The users, five year old children, had to count egg marks in dinosaur nests and to organise them across different nests using same/different estimations. Two test groups had two different motion interaction patterns: arm motion, and full body motion. There were three consecutive tasks. We demonstrate that children performed the numerical task at different speeds. The children in the arm motion group had more errors and hesitations, but they also were less engaged, often abandoning the correct motor responses. We conclude providing a list of requirements that computer games should present when training mathematical competences.

Keywords: mathematics, video game, body motion, learning

1 INTRODUCTION
Since their early days, digital games have instigated strong reactions and controversial opinions. Their wide public acceptability has allowed them to be implemented world-wide, mostly among young users. Naturally, some education experts have highlighted the impacts and risks associated to the use of such games. On the other hand, many have provided new insights on the benefits of a digital game-based learning approach (e.g. [1]). Such approach should provide greater potential for learning, larger attention spans than in traditional classes, and more proactivity [2].

Although there are no doubts about the potential of interactive game in pedagogic contexts, the game type and structure can mark the difference between an effective game and a failed game. Some studies have demonstrated that the best elements in an educational game involve 3D adventure and strategy. Other important elements in a game are logic, memory, visualization and problem solving [3]. Such elements are also found in the learning process.

The game dynamics, as well as the amount and quality of the interactions made available to the player directly affect the gaming experience [4]. An increase in body movement, imposed or allowed by the game controller, results in an increase in the players’ engagement level [5]. The full body experience facilitates the feeling of presence in the digital environment, enables the affective aspects of human-human interaction, and unleashes the regulatory properties of emotion [6].

The impact of learning with digital games is only now starting to be addressed in comprehensive ways. Many elements remain unexplored. Games are rapidly evolving, becoming more immersive, requiring
more proactivity, and body motion. In this study we present a preliminary approach to the impacts of motion interaction on game effectiveness. We compared two groups of players, one moving mostly the arms, and the other with whole body movement, in a mathematical task.

2 METHODS

2.1 Participants

The experiments we report had as participants 18 volunteer children from a kindergarten in Guimarães, Portugal. All children had written informed consent from their caretakers. All children were 5 years old and had normal development indicators. 8 participants were male and 10 were female.

16 reported having a computer at home. All used the computer mostly for playing. 6 used it every day, 6 used it on weekends, and 3 only rarely used it. 8 participants had other gaming platforms, such as Nintendo DS, PlayStation Portable, or PlayStation Vita. All used these systems to play. 3 played daily, 3 on the weekends, and 2 only rarely. 5 participants had a motion based gaming platform, such as a Nintendo Wii, an Xbox 360 with Kinect, or a PlayStation Move. They all used these systems to play and they played mostly on the weekends.

2.2 The game

The game “Matemáquina do Tempo” (Time Mathmachine) was designed by a consortium of research institutions and technology companies, with the objective of developing new technologies to stimulate mathematical competences in young children. This game follows the official educational programs while promotes the motor involvement of the children. It was designed for a market-implemented platform: the Microsoft’s XBOX 360 with KINECT.

The game started in a school, but soon the main player was transported in time, to the Jurassic period. The user then had to walk in a complex environment, lead by “+” signs, while performing several motor activities, motor and mathematical activities, and purely mathematical. The task tested in this study comprised both motor and mathematical elements.

The player started by running in a green field when his/her computer help, the “MAT”, said: “Shhhut! Don’t make any noise! Walk slowly. Do you see these nests? [Four nests are presented]. They have dinosaur eggs, but the eggs are all in the wrong place. The dinosaurs are restless because of that” [moving dinosaurs are visible in the distance]. There was one nest close to the player and three nests farther in distance. There were five eggs in the closest nest: one egg had no marks, another had one mark, another two marks, another three marks, and two eggs had 4 marks. One of the distant nests had 3 mark eggs, another had no mark eggs, and another had no eggs.

The task then comprised the following steps:

- Instructing that by the end all nests had to have eggs of the same type.
- Asking the player to start by choosing an egg with no marks and placing it in the right nest;
- Asking the player to select the egg with two marks and placing it in the right nest (a very difficult task since there were no nests where eggs of two marks could be found);
- Asking the player to select and place the egg with three marks.
While playing the four task steps, two groups of players performed the task differently. One group had to point to the eggs, then pick them up from the ground (lowering knees and arms), point at the target nest, walk, then take them and place them in the ground (lowering knees and arms). The other group only had to point at the target eggs and then at the target nests. The egg automatically flew from one nest to the other. Also, the body motion group had to run from an angry dinosaur, and hide in the grass (lowering body) after moving each egg.

By the end of this task, both groups had to run to a tree, climb it, take a prize, come down again.

2.3 Apparatus

These experiments were implemented in a big room with enough space for the children to move. The room had a big TV screen, placed on a small table, and leveled at the children's heads (figure 2). There was a computer equipped with the KINECT, where the game run, and a video camera.

In the room with there were always three children: the player, a friend of the same class watching, and a child that just finished the game and was answering the questionnaire. Other than the children, there was the engineer, who was taking care of the technical aspects, and took care of the “wizard of oz” procedures; there was the experimenter, also narrating the instructions; there was an educator; there was an additional experimenter running the questionnaires.
2.4 Procedure

Children were placed in front of the screen. After the first instructions, they posed so that the system would recognize their body and movements. Then they run to the nests. The nest part of the game was all played through the method of wizard of oz [6]. The Wizard of Oz technique is as efficient way to examine user interaction with computers. The experimenter (the "wizard"), pretending to be a computer, responds to user queries by pressing function keys to which responses have been assigned. This way, we made sure that all interaction during the mathematics activity was the same for all users, and that no technical problems created differences between children. After the nest part, children climbed the tree for the reward thus finishing the task. All the gaming activities were videotaped from the back of the children (see figure 2), to protect their anonymity.

Both groups, body movement and arm movement, were distributed randomly.

After the game, all participants answered a questionnaire. They answered about their computer game experience, other game platform experience, and motor based digital game experience. They then answered a small questionnaire about the game, how the classified it, their fondness of mathematics, their interest in playing such games, the interaction quality, the help quality, and their favorite elements.

Results are presented below.

3 RESULTS

We will first present the result about children’s evaluation and surveys. We will then present the data about the interaction quality and the mathematical task.
3.1 Children’s evaluation and surveys

Generally, all children appreciated the game. Both groups enjoyed the game. 78 percent of the participants reported that the game was very fun, 22 percent reported that the game was fun, and none categorised it as not fun.

When classifying the game quality, there were clear differences between groups (figure 2). In the group with full body motion, 67 percent gave “Very Good” estimates, against the 22 percent of the arm motion group.

Figure 3. Game quality classifications in both experimental groups; full body motion group at the left and arm motion at the right.

About their estimates on the effect of the game over math learning, both groups reported feeling that they learned something (72 percent).

88 percent said that they liked mathematics, and 94 percent said that they would like to learn with games like this, and that they hoped their school would adopt these games. Also 94 percent said they would like to play this game again.

About the interaction quality, 72 percent considered that navigating this game was easy. But in the full body motion group children considered that the gestures were mostly “very easy”, while in the full arm group they considered them to be only “easy”.

Overall, children considered that the game scenario was very beautiful. Interestingly, the full body motion group considered that help pictures more helpful (100 percent) than the arm motion group (55 percent). Possibly as a consequence, the first group felt like they would not be able to play the game without the help, while the other group didn’t report this necessity. This result highlights the importance of presenting good motion models to help in the motion based digital games.

About the elements that children preferred in the game, all children pointed out interactive movements such as picking up the eggs, running from the dinosaur, and climbing the tree. Only a smaller percentage (33 percent) also referred the other, non interactive movements, such as walking or pointing. This element highlights that it is not only the movement element in the game that is important, but also the interactivity with other objects or characters.

3.2 Interaction quality and the mathematical task

Results of the mathematical task relate only to the moments when the participants had to point at the correct nest. This part was the same for both groups: after selecting an egg, they had to point where it should go and lock their answer.

On average participants took 19.9 seconds to finish each task. The arm movement group took longer, about 29.7 seconds, and the body movement group was faster, 10.1 seconds on average.
Looking at the time it took to complete each egg placement (figure 4) it is noticeable that the second task was the most difficult, taking more time for both groups (66.5 seconds for the arm group and 22.14 seconds for the full body group). This task was indeed expected to be more difficult, as there was no nest with the same number of marks as the ones in the egg to be placed.

More importantly, from the analysis of time to completion, it stands out that the full body group was consistently faster in completing the activity than the arm group. In task 1 the arm group took 12.88 seconds, while the full body group took 4.29 seconds. In the last task, the arm group took 9.75 seconds and the full body group took 3.86 seconds.

There was also a learning effect. Both groups improved in time to completion from the first to the last task. Here, it was the arm group that most benefited from experience, with a mean gain of 1.71 seconds, against the improvement in 0.43 seconds of the full body group. It should however be noticed that even in the last task the players of the arm group were still not as fast as the players of the full body group.

Regarding other qualitative indicators in performance, such as number of errors and hesitations (figure 5), there were also differences between each group. On average, the arm movement group hesitated 4.25 times during the whole exercise, while the full body group hesitated 1.43 times. About the average amount of errors, the arm movement group had 2.5 on average, and the full body movement group had 1.

Finally, we analyzed the motor engagement. We suspected that those participants in the full body condition were overall more engaged in the activity, and that this might correlate with the results. We assessed the amount of times children dropped their arms, loosing the correspondence between the displayed activity and their own. We found that indeed children in the arm motion group made more motor faults (3.13 on average) than children in the full body motion group (0.57).
4 CONCLUSION

In this project we analysed how children perform a mathematical task with different levels of motion engagement. In one group participants only moved their arms, and in the other they moved the whole body.

We found that game quality classifications were clearly distinct. The game was mostly experienced as very good by the full body group, but only as good by the arm group. Interestingly, all children preferred the interactive parts of the game to other elements.

The full body group was consistently faster than the arm group in finishing the mathematical tasks. Both groups improved in time to completion from the first to the last task, but still the arm group did not get as efficient as the full body group. We cannot draw strong conclusions from this data, as there were only 9 children per group, but data suggests that there was indeed a benefit from the full body movement.

The arm group had overall more hesitations and errors than the full body group. Interestingly, they also broke more the movement-display congruency, lowering the arms. We interpret that the arm group was not as engaged as the other group, which is also consistent with previous literature [6]. The body motion in human-computer interactions might provide more feeling of presence. We argue that this element might bring benefits in learning tasks, by allowing more attention and devotion to the tasks. We therefore propose that educational games for younger populations should have an enhanced level of interactivity.
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