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Measuring cognitive load in practicing arithmetic using educational video games on a shared display

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ABSTRACT

The benefits of introducing educational video games in the classroom are many. Due to the widely available number and sizes of screens, and the learning outcomes shown by the Interpersonal Computer make this an emerging technology that should be considered for the classroom, technology that shares display characteristics with tabletops. An important factor to consider in this sort of technology is the position and amount of information displayed. The purpose of this research is to study the effect of the position on the screen of displayed information and the amount of information received by each of the students who share the workspace with respect to the acquired knowledge. We learned that students that worked with more objects and had more neighbors improved significantly less in their learning, a result that can be explained through the Cognitive Load Theory.

1. Introduction

Different studies show positive effects of the use of educational video games in the classroom, both in student achievement and attitude toward learning, compared to traditional teaching (Lou, Abrami, & d'Apollonia, 2001). Using these applications, it is possible to develop different learning styles (Connolly & Stansfield, 2007; Ziemek, 2005), since the speed and difficulty level can be adjusted according to the profile of each player (Echeverría, Barrios, Nussbaum, Améstica, & Leclerc, 2012).

The use of educational games in the classroom is commonly done with desktops, laptops, mobiles, augmented reality, interactive tables and tablets (Echeverría, Améstica, et al., 2012; Goh, Shou, Tan, & Lum, 2012; Gwee, San Chee, & Tan, 2011). An alternative is the Interpersonal Computer with shared display, which allows all students in a course to interact simultaneously while the teacher can monitor the students' work to mediate those in need (Alcoholado et al., 2012). Massification in number and sizes of screens (Seyed, Burns, Costa Sousa, & Maurer, 2013) make shared display studying become relevant.

According to Kaplan et al. (2009), the Interpersonal Computer is defined as a single computer with multiple input devices and a shared display. It allows multiple users located in the same space to interact simultaneously. Each user controls their own input device but shares the information that is displayed. This technology is ideal for schools in developing countries, where the cost of computing infrastructure can be an initial barrier (Trucano, 2010). This is because it minimizes the number of machines that are required, as well as the need for technical support.

Various studies, such as Alcoholado et al. (2012), Beserra, Nussbaum, Zeni, Rodriguez, and Wurman (2014), Rosen, Nussbaum, Alario-Hoyos, Readi, and Hernandez (2014), Caballero et al. (2014); Echeverría, Améstica, et al. (2012); and Villalta et al. (2011), have shown that using Interpersonal Computers with a Shared Display and one mouse per student can improve learning outcomes when used in the classroom. Furthermore, Alcoholado, Diaz, Tagle, Nussbaum, and Infante (2014) compare the use of the Interpersonal Computer with the use of the Personal Computer. They do not find any significant differences in terms of learning outcomes and conclude that the key characteristic shared by both technologies (the provision of feedback) does not affect the teaching/learning process. This is regardless of whether the feedback is private (through an individual screen) or public (through a shared screen).

In addition to this, the fact that children have their own objectives throughout the activity favors both student interaction and motivation. Therefore, the control that students have over their input device leads them to become participants in their own learning process (Infante, Hidalgo, Nussbaum, Alarcón, & Gottlieb, 2009).

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Similarly, activities that use a shared display and give students individual control of their input device show lower levels of boredom and disruptive behavior in the classroom (Infante et al., 2010). This in turn suggests a higher level of involvement in the activity (Scott, Mandryk, & Inkpen, 2002).

At an Interpersonal Computer all children share their workspace, or each can have their individual personal space. The first enables the development of activities that incorporate cooperation and collaboration skills (Amershi, Morris, Moraveji, Balakrishnan, & Toyama, 2010), key components for 21st century skills development. The second allows the creation of individual activities that provide personal feedback and respect the learning pace of each of the participating children (Beserra et al., 2014).

As with Interpersonal Computers, Tabletops also allow for individual, cooperative and collaborative work spaces. These spaces are generated in activities where the objectives can be both individual and collective. Considering that the objective of Tabletops is focused mainly on cooperative/collaborative work in a shared space, where one or more of the users are required to carry out individual sub-tasks, such tasks can be assisted by creating individual work spaces within the collective space. For example, in Morris, Lombardo, and Wigdor (2010), for collaborative web searches, the users can access a tool which allows them to do an online literature search by creating an individual work space and allowing the other users to continue working on the main search or in the previously found results. Similarly, Martínez, Collins, Kay, and Yacef (2011) presented an activity involving a cooperatively-built concept map where each student built their own concept map before linking it to the other students' maps. This coexistence of individual and collective work spaces in Tabletops can be observed in both pedagogical and game-based activities. For example, in a ludic activity related to themes such as sustainability, planning and urban development, the collective space represents a developing urban region and the individual spaces are composed of different elements that define the impact in the development of the region and these are assigned the different children (Antle, Tanenbaum, Bevans, Seaborn,, & Wang, 2011). The coexistence of these individual and collective spaces produces extraneous information which could affect how the user carries out the main activity.

An important factor to consider when working on a shared screen is the difficulty the child may experience in focusing on their work space. By simultaneously deploying workspaces of a large number of students that may be changing constantly, the large set of visual stimuli can become a distracting factor considering that the attention span is limited with respect to the stimuli that is possible to perceive simultaneously (Cowan, 1988).

Considering that in a shared screen with each child having their own workspace, its position considering the number of spaces adjacent to it may be internal (with surrounding work spaces) or external (workspace in the periphery) (Figs. 3 and 4). Being visual information, the human eye perceives visual information simultaneously within a focal vision (looking at an object directly, capturing an image on the retina) and beyond (which surrounds the object with a lower resolution) (Grad, Graham, & Stewart, 2007). Thus, the focal information that the students consider while working, is located within their work space, and the rest of the elements in the common display, which are not necessary for the student activity and correspond to peripheral information.

Designing a game includes an attractive and stimulating graphical space (Whitton & Whitton, 2011) consisting of graphic objects and characters that represent the staging of the narrative of the game (Wei, 2010). All this may require a large amount of information to achieve the objectives of the game (Grad et al., 2007); information that on a shared display may create a problem of cognitive overload. Considering that cognitive load is the total amount of mental activity consciously processed to solve a task (Paas, Renkl, & Sweller, 2003), all elements present for the player on the display should be considered, because while processing all the information present, the interaction of the player with the game can become difficult (Adinolf & Turkay, 2011).

Considering the aforementioned, our research question arises: when a display is shared between different students, each with their personal workspace, to develop educational video games, how does the student's position relative to the shared screen and the amount of information displayed relate to their acquired knowledge?

2. Methodology

2.1. Sample

To measure the impact of the student's position on the shared screen of the Interpersonal Computer relative to knowledge acquired by them, a study was conducted in a private school in Santiago, Chile, using 4 s-grade classes totaling 141 children of ages between eight and nine (Table 1). Of the four classes, two classes used the Ludic version (Fig. 1(b)) and the other two classes worked with the non-Ludic version (Fig. 1(a)). Only students who took part in both assessments (pre -and post-) were classified as "Participant students".

The participants, both girls and boys, are indicated respectively in the third and fourth rows of Table 1. To ensure that the intervention was similar in each of the students, students' mean attendance was calculated, Table 1, which corresponds to the average number of sessions attended by the students in each class, value obtained from the data stored by the system in each session.

2.2. Assessment Instrument (pre and post-test)

This consisted of an individual evaluation of each student's previous knowledge of mathematics, adapted from the instrument used in Alcoholado et al. (2012). Prior to the study, the participating teachers reviewed the instrument in order to confirm its validity in terms of its educational content and its effectiveness in measuring acquired knowledge. The evaluation contained 45 mathematics exercises designed to identify the 2nd graders' skills in operations of addition, subtraction, multiplication and division and lasted a maximum of 45 min. These quantitative data was collected through instruments on paper.

To ensure the reliability of these instruments (pre and post-test), they were analysed for each of the participating classes under the criteria of Cronbach's Alpha, Table 2. According to Bland and Altman (1997), a value of higher than 0.6 for Cronbach's Alpha indicates that the applied test is acceptable for classifying students, based on the content delivered.

2.3. Applications used

To answer the aforementioned research question two educational video games for an Interpersonal Computer with a shared

Table 1
Class characteristics.

Classes	Technology			
	Ludic A	Ludic B	No Ludic C	No Ludic D
Students in the class	36	35	34	36
Participating students	28	33	33	34
Participating girls	11	21	17	18
Participating boys	17	12	16	16
Mean students attendance	12.91	12.88	13.19	12.59