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WeDRAW: USING MULTISENSORY SERIOUS GAMES TO EXPLORE CONCEPTS IN PRIMARY MATHEMATICS

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ABSTRACT

In this paper we introduce weDRAW, a project to support primary school children in the exploration of mathematical concepts, through the design, development and evaluation of multisensory serious games, using a combination of sensory interactive technologies. Working closely with schools, using participatory design techniques, the games will be embedded into the school curricula, and configurable by teachers. Besides application to typically developing children, a major goal is to explore the benefits of this multisensory approach with visually impaired and dyslexic children.

Keywords: Mathematics, Multisensory, Serious Games, Geometry, Arithmetic.

INTRODUCTION

weDRAW (http://www.wedraw.eu) is a two-year project which aims to mediate the teaching of primary school mathematical concepts, such as geometry and arithmetic, through the design, development and evaluation of multisensory serious games, using a combination of sensory interactive technologies, taking into account developmental psychology and classroom interaction. The project proposes an embodied and enactive approach to learning. Enactive knowledge is not simply multisensory mediated knowledge, but knowledge stored in the form of motor responses and acquired by the act of doing. The games will integrate visual, sound and haptic feedback, in response to whole body movement. In this paper we will introduce the project and discuss work carried out to date.

MULTISENSORY LEARNING

The past two decades have seen increased exploration of technology to supporting teaching and learning (Laurillard, 2012, p. 2; Roschelle, Pea, Hoadley, Gordin, & Means, 2001), with a recent emphasis on multimodal and multisensory interaction. While concepts of embodiment are not new, the growth of ubiquitous computing and the possibility to enhance physical environments and interaction have brought discussions around embodiment to the forefront, emphasising the role of experience, the sensory body, emotion and social interaction for cognition and learning (Barsalou, 2008; Shaun Gallagher, 2005; Smith & Gasser, 2005; Wilson, 2002). There is evidence that mathematical cognition is embodied (Lakoff & Núñez, 2000), since it is grounded in the physical environment, and based in perception and action (Alibali & Nathan, 2012). That mathematical understanding arises from physical experiences suggests that learning environments need to introduce concepts through physical means, such as action or gestures. The importance of engaging with other modalities besides the visual for learning is not new. According to Kalogirou, Elia and Gagatsis (2013, in Jones & Tzekaki 2016), in the context of geometry, visual perception provides “direct access to the shape and never gives a complete apprehension of it” (p.129-130). Hall & Nemirovsky (2012) highlight the value in experiencing the difference between looking down on a geometric figure on paper or being inside it, or the tactile experience of that same figure. Several recent studies show the benefits of embodied learning approaches in primary mathematics (e.g. Goldin-Meadow, Wagner Cook, & Mitchell, 2009; Manches & O’Malley, 2016).

The use of di erent modalities can reduce cognitive load and improve learning (Moreno & Mayer, 1999), as well as o er new opportunities. Multimodal feedback has been shown to support skills development in children with dyslexia, for example, a musical training programme including cross-modal activities such as rhythm production, which has been shown to improve the reading problems experienced by dyslexic children (Habib et al., 2016). Another opportunity is to support learning for visually impaired children through the provision of additional stimuli. People who have never had any visual experience (congenitally blind), or who have lost their vision in early infancy (early blind) are seriously impaired when performing spatial tasks compared to blind participants who have lost their vision after becoming an adult (late blind) or sighted participants. As a result, complex computations that rely on such types of representations are more di cult (Thinus-Blanc & Gaunet, 1997), which impacts the ability to understand concepts of geometry. However, research from psychophysics and developmental psychology suggests that children have a preferential sensory channel for learning, and that vision is not always the dominant channel, especially for children under 8-10 years of age (Cappagli & Gori, 2016; Gori, Del Viva, Sandini, & Burr, 2008). For example, auditory feedback has been shown to improve spatial cognition in visually impaired children (Finocchietti, Cappagli, & Gori, 2017; Gori, Sandini, Martinoli, & Burr, 2014). The use of body movement has been shown to deepen and strengthen learning, retention, and engagement (Klemmer, Hartmann, & Takayama, 2006). Body movement is naturally associated with space and could be used to reinforce the understanding of spatial concepts which is weakened in visually impaired individuals.

TECHNOLOGY AND SERIOUS GAMES

Games and play are an important part of the social and cognitive development of young children (Nicolopoulou, 1993). 'Serious games' are (digital) games with a purpose beyond pure entertainment. There are related, and sometimes overlapping domains, such as e-learning, edutainment, and game-based learning, but the goals of serious games go much further (Susi, Johannesson, & Backlund, 2007) and they can motivate learners in new ways (Prensky, 2005). Consideration of serious games is often limited to video games, played on a desktop computer, however this reduces the affordances available for multisensory learning. Digital technology has the potential to create new educational materials which exploit different sensory modalities, offering opportunities for new ways of thinking and processing information, and opening new avenues for creativity. The goals of most serious games are to facilitate learning higher order thinking skills through characteristics of gameplay. However, a serious game will not succeed just because it is a game with educational content. To be effective, instructional designers and video game designers need to understand how game characteristics such as competition and goals, rules, challenges, choices, and fantasy can influence motivation and facilitate learning (Charsky, 2010). Serious games have previously been applied to the learning of STEM subjects, but largely focused on teenage children, and as a result lack a developmental perspective (Berta, Bellotti, van der Spek, & Winkler, 2015; Ritterfeld, Cody, & Vorderer, 2009, Chapter 10,11). Renewed neuroscienti c understanding about how sensory modalities interact, and are integrated during development, need to be taken into account during game design. Educational research has also found that working in pairs or small groups can have beneficial effects on learning and development, particularly in early years and primary education (Benford et al., 2000), hence weDRAW games will aim to foster collaboration and interaction between children, as well as with the teacher, in the classroom.

RESEARCH PROGRESS

Working closely with primary school teachers, weDRAW makes use of observations of everyday classroom activity and practice, interviews and ongoing workshops to inform design requirements. In order to identify the most appropriate mathematical concepts to support through digital multi-sensory activities, the project team has collected data from teachers in UK and Italy, through teacher workshops and questionnaires (completed by over 100 teachers). The key areas of the primary mathematics curriculum that children find challenging, and where multimodal and multisensory engagement hold particular promise were found to include isometric transformations, symmetry, adding and multiplying fractions, measurement and estimation, and making the link between fractions, percentages and decimals. Interestingly, the concepts described as most challenging were not consistent across the levels or ages of children. This is partly because some concepts are not introduced to children until a certain age, and partly because the complexity of a concept increases as the children progress from year to year of the national curriculum (Department for Education, 2013). This has implications for the design of the games, to ensure that stretch and challenge is appropriate for all children in the target age range (6-10 years old), whilst providing an accessible entry point that develops knowledge through exploration (Price, Duffy, & Gori, 2017). For visually impaired students specifically, young children were described as finding it difficult to conceptualise arithmetic magnitude, in particular in the use of number lines where negative numbers were included. A geometric challenge was understanding the beginning and end of a shape; visually impaired students requiring reference points on a spatial and temporal continuum.

During teacher workshops, participants were supported to imagine what a future solution might look like (Rosson & Carroll, 2002), using participatory design techniques. These were then developed into design scenarios. Four workshops were undertaken with teachers in UK and Italy: three involved teachers from mainstream schools, and one involved teachers from a school for visually impaired children. Some common classroom activities described by the teachers in brainstorming sessions, such as constructing physical shapes using paper to demonstrate nets, or folding paper to explore symmetry, were thought to lend themselves more naturally to multimodal approaches than others, such as number lines. Colour was commonly recognised as a useful visual resource, but audio or tactile resources were perceived as less commonly used in the classroom. However, some activities described by the teachers, such as manipulating paper into 3D shapes, folding to find lines of symmetry, or using a trundle wheel suggest that there may be an unrecognised tactile or audio aspect that can be exploited by the weDRAW project.

CONCLUSION

Working with the concepts identified, we will encourage the creative capacities of children, as well as support the role of the teacher in the learning process. The suite of games created will be flexible and modular, allowing teachers to customise content to best suit their students' preferred mode of learning (i.e. audio, tactile, motor and visual), whilst unified by an overarching game story and narrative. A hardware and software platform will be developed to support this approach, and three serious games designed to evaluate it. The adoption of an embodied and enactive learning paradigm will allow motoric behaviour to be mapped onto the preferential sensory modality for typically developed children, or onto an alternative modality for impaired children. As a result, the same learning paradigm can be applied to all children interacting together in the classroom, reducing differences and social barriers.

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