Interacting with Videogames in Adolescence: Effects of Graphic Visualization on Perceived Presence and Visuospatial Competences

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Abstract. The study here described had the aim of studying the effects of the interaction with videogames characterized by different modalities of graphic visualization (two-dimensional vs. three-dimensional) on presence and visuo-spatial competences. Participants were 129 adolescents (74 M and 55 F) aged 14–18 years old (mean of age = 16.11; SD = 1.31), recruited in a high school in Northern Italy. Participants were instructed to use for a week on their home PC a specific videogame and were divided in five experimental conditions: 2D Tetris, 3D Tetris, 2D Adventure, 3D Adventure, control. Videogames provided to participants were chosen so to have a continuum in terms of complexity of graphics, complexity of interaction possibilities and degree of immersivity. At the end of the week of playing with the given videogame, participants were administered specific checklists for measuring the degree of presence experimented during the interaction with the videogame and their visuo-spatial performance. This results show that there is a strong and direct correlation between the degree of complexity, immersivity and cognitive demands of videogames and the level of presence conveyed. Results also show that some of the visuo-spatial abilities are progressively and positively improved as the complexity of the graphic environment increases.

Keywords: Presence · Videogames · Visuo-spatial abilities · Graphic visualization · Immersivity

1 Introduction

Presence can be defined as a medium-related function, i.e. the perceptive illusion of *non-mediation*, in a context of mediated environment [1]. This effect is due to a cognitive disappearance of the medium from the conscious subjective experience [2].

The term "presence" in its present meaning was subject of scientific debate from 1992, when Sheridan [3] used it instead of "telepresence" as a result of the first experimental studies in the field of virtual reality applied to remote control of equipment. Differently from the early Nineties, nowadays most of virtual reality technology is used to generate environments to foster participation in socio-cognitive activities via

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interaction with a computer. The common ground is that the participant ceases to think about himself as interacting with a computer and starts to directly interact with the virtual environment. The virtual environment allows the participant to project his cognitive, perceptive and motor abilities in a simulated environment, and the feeling of presence is the consequence of a seamless and successful performing of an action in that environment [4, 5].

The similarity between the feedback to an action in the virtual environment and the real feedback to the same action in the real world is crucial in fostering a sense of presence. From a perceptual and cognitive point of view, the subject implicitly evaluates the contents of virtual environments in terms of opportunities and affordances: as the formers increase, the sense of presence is more likely to occur. The result of the increase in the sense of presence is a sort of paradoxical "invisibility" of the medium [6] and a sense of inseparability between the self and the virtual environment [7]. Presence has also a clear effect on emotions, in a "circular" path of mutual influence [8].

More recently, one of the most intriguing applications of virtual reality is the world of videogaming: modern videogames often can boast among the most sophisticated and complex virtual environments in the consumer market. The illusion of being in a synthesized virtual environment is maximised in the top productions, both from an aural and a visual point of view [9]. Modern videogames are generally characterized by very complex virtual environments in which the players can interact in many ways, and conceived to let the player have the impression that there are no boundaries and no limits to their exploration (e.g. the so-called "free roaming games").

Videogames are also one of the most widespread forms of entertainment among children and adolescents, and often represent the first mean of approach with the information technologies for the new generations. In the developmental psychology literature, videogames have been linked with potential negative effects such as increased aggression due to violent contents [10], addiction [11] and seizures [12]. The literature has also clearly pointed out that videogame play can exert significant positive effects in terms of cognitive processes, such as visuospatial abilities [13], problem-solving skills and inductive reasoning [14].

Given these findings, it appears of interest to link the study of presence to the strong literature on the effects of videogame use. A few researches studied the degree of graphical complexity of videogames in relation with the sense of presence. Ivory and Kalyanaraman [15] found that the improvement in terms of graphics between mid-1990s and 2003 games led to stronger sensations of presence in their participants. Bracken and Skalski [16] found similar results: undergraduates that played a high definition (HD) version of a modern videogame felt a stronger sense of presence than controls who played a standard definition (SD) version of the same videogame.

1.1 Aims of the Research

Moving from these results, the present study has the aim of deepening the knowledge about the effect of visualization on both the sense of presence conveyed by videogames and the visuo-spatial competences. Given the paradigmatic shift seen in the last 20 years in the videogame industry (i.e. the introduction of complex and real-time three-dimensional graphics), assessing the effects of the different types of visualization it is of some importance. This holds even truer when thinking about the learning potential embedded in videogames: choosing the "right" balance between immersion, presence and conveying of contents to be learned could be crucial in order to design videogames for learning purposes.

2 Materials and Methods

2.1 Participants

Participants were 129 students, aged 14–18 (mean = 16.11; SD = 1.31), recruited in a high school in Northern Italy. 74 (57.4%) participants were male and 55 (42.6%) female. No gender differences in terms of mean age were found at *t* test for independent samples ($t = .88$ ns).

2.2 Procedure

The research was approved by school managers and was proposed to students during curricular activities in their classrooms. Parents of the participants signed a written consent to allow their children to take part in the study. Participants were randomly assigned to five experimental conditions: 2D Tetris, 3D Tetris, 2D Adventure, 3D Adventure and control condition. No age differences were found between the five experimental conditions at ANOVA ($F = .01$ ns).

Participants were tested for visuospatial abilities with five subscales of the "Kit of Factor Referenced Cognitive Tests" [17], before they were given a CD-ROM containing a specific videogame (described below) and were asked to play with the provided videogame for a week on their home PCs. Participants were overtly asked to refrain from using other videogames during the week.

Videogames provided to participants were chosen so to have a continuum in terms of complexity of graphics, complexity of interaction possibilities and degree of immersivity, starting from 2D Tetris (the simplest) to 3D Adventure (the most complex):

- 2D Tetris: two-dimensional version of the classic Pazhitnov's 1984 puzzle game.
- 3D Tetris: three-dimensional version of Tetris, with a rotation of shapes in the three axes instead of one.
- 2D Adventure: for both the adventure conditions, the game "The Secret of Monkey Island" was chosen. Being an adventure videogame, the player need to solve puzzles in order to progress with the plot. The player interacts with the videogame via a two-dimensional interface, controlling a character and pointing with the mouse over various objects and characters and performing on them a fixed set of actions.
- 3D Adventure: participants assigned to this condition played with the fourth episode of the "Monkey Island" series. This episode shares the same adventure structure of the first episode but is displayed via a real time three-dimensional environment. The

player controls the character and performs actions via a combination of mouse and keyboard inputs.

The videogames were chosen in order to avoid any possible violent content and for their ease of play. Thus, there were two distinct features of variation in experimental conditions:

1. depth of interaction: Tetris provided limited interactive affordances, giving the repetitiveness of action, whereas the Adventure provided more complex problem-solving puzzles and a degree of free exploration;
2. visualization: 2D isometric representation of shapes and environments vs. 3D real time reconstruction of shapes and landscapes.

At the end of the week of training with the videogame, participants were re-assessed for visuo-spatial abilities and were administered the Italian version of the ITC-SOPI questionnaire [18] in order to assess the degree of presence experimented during the videogame play. Questionnaires were administered the day after the end of the one-week training with videogames, in order to make sure they had still a vivid recall of their gaming activity. Participants were also asked to state their previous experience with videogames in terms of mean of hours per week spent videogaming.

2.3 Measures

Visuo-spatial abilities were assessed prior and after the training with videogames by using five subscales of "Kit of Factor Referenced Cognitive Tests" [17]. The subscales administered were:

- Matrix of points (CF-3).
- Recognition of identical figures (P-3).
- Reconstruction of images (CS-1).
- Rotation of figures (S-1).
- Rotation of cubes (S-2).

Cronbach's alpha was .88.

In order to assess the degree of presence experimented by using the videogames provided, participants were administered a specific measure, the ITC-SOPI by Lessiter et al. [18]. The instrument specifically focuses upon the subjective experience when interacting with a medium, is comprised of 42 items on a 5-point likert scale.

The instrument provides four subscales, each measuring a distinct feature of presence:

- SP (physical space): measures the feeling of being physically placed in a virtual environment. This is related also to a personal evaluation of the sense of "being there".
- ENGAGE (engagement): measures the degree of subjective psychological engagement in the virtual experience.
- ECO (ecological validity): this subscale measures the overall appeal and believability of the environment and its content, and to perceive them as lifelike and real.

- NEG (negative effects): this subscale refers to potentially negative feedbacks from the interaction with the medium, such as dizziness, headaches, nausea.

Cronbach's Alpha of the ITC-SOPI was .97.

3 Results

We performed a MANOVA to compare the visuo-spatial performance before and after the experience with videogames, and the degree of presence conveyed by the different experimental condition. In order to precisely pinpoint the specific contribution of the experimental conditions on both visuospatial abilities and presence, we splitted the two facets of the experimental condition and inserted them as fixed factors: "visualization" (i.e. 2D vs. 3D), and "interaction" (i.e. high interaction, Adventure vs. low interaction, Tetris). To control for prior experience with videogames, we inserted the hours per week of videogames use as covariate. We found two significant main effects: one of visualization (Wilks' $\Lambda = .315$, $F = 7.74$, $p < .001$, multivariate $\eta 2 = .685$) and one of interaction (Wilks' $\Lambda = .135$, $F = 22.76$, $p < .001$, multivariate $\eta 2 = .865$). Interestingly, we found no significance for the combined effect visualization * interaction. As can be seen from Table 1 (only significant scores reported), follow-up ANOVAs indicate a clear and significant trend among the main facets of experimental conditions (interaction and visualization) as regards presence: the degree of presence steadily increased from the least immersive and interactive condition (2D Tetris) to the most immersive and interactive condition (3D Adventure). The experimental condition also has an effect on some of the visuospatial competences: CF-3 and S-1 subscales showed a clear increase from pre- to post-test, and the more complex and immersive the environment, the more increment was found. These results hold true regardless habitual experience with videogames (weekly hours were controlled as covariates).

Table 1. Differences between experimental conditions in terms of presence and visuo-spatial abilities.

Experimental condition mean scores					Variable	*F*	η	*p*
2D Tetris	3D Tetris	2D Adv.	3D Adv.	Control				
1.80	2.11	2.62	3.23	–	SP	76.38	.761	*.001*
2.59	2.86	3.54	3.83	–	ENGAGEMENT	44.66	.650	*.001*
1.47	2.18	2.35	3.02	–	ECO	80.07	.769	*.001*
1.50	1.35	1.54	1.59	–	NEG	2.82	.105	*.05*
20.26	21.42	20.23	22.11	20.47	CF-3 (pre-test)	2.72	.036	*ns.*
23.73	23.89	23.66	27.05	22.78	CF-3 (post-test)	4.10	.054	*.05*
43.36	44.36	38.71	48.00	40.96	S-1 (pre-test)	3.18	.042	*ns.*
47.73	49.36	44.42	53.61	45.54	S-1 (post-test)	4.08	.054	*.05*

4 Discussion

The aims of the research were to verify if the graphic visualization of the videogame could be related to the degree of presence experimented by the player and to an increase in visuospatial competences. Data show that participants who played the three-dimensional versions of the games felt a higher degree of presence than participants who played the two-dimensional versions.

Of more interest is that – regardless of graphic complexity – participants who played the adventure obtained higher scores in terms of presence than participants who played the puzzle game. This clearly calls into play the level of cognitive challenge and cognitive complexity of tasks as a key factor in the fostering of presence. Put in other words, the level of graphic complexity is only a part of the picture: it seems that the level of challenge in terms of cognitive skills is just as important as the formal properties of the graphics.

Nonetheless, the level of realism in terms of virtual environments is also a key factor, at least for the impression of being physically placed in a virtual environment. The more detailed and lifelike the graphics are, the more the subject gains the feeling of "being there". In our sample, this is clearly shown by the ICT-SOPI "SP" subscale: mean scores of the 3D Adventure experimental condition almost double those of 2D Tetris condition and are roughly the 20% higher than even the 2D Adventure condition. Regarding the "ENGAGE" subscale we can detect the same trend: players enjoyed the more detailed and vivid experience of both the Adventure experimental conditions over the more simple and less interactive gameplay of Tetris. If we consider the "ECO" subscale, data suggest that players felt the Adventure environments as more ecologically credible than the Tetris ones. This comes quite obvious since both Tetris are puzzle games whose objectives are not to recreate a fictional world. Finally, regarding the "NEG" subscale, none of the experimental conditions conveyed substantial uneasiness in the participants. Only the 3D Adventure causes a marginal discomfort, probably due to the difficulty to detect the "hotspots" (the areas where the player could interact with objects) in the environment. No instances of motion sickness were reported by participants.

Also, our results show that the level of presence and complexity of the videogame could have some effects also on the increase of visuo-spatial abilities. Our participants shown better performances in the task of completing matrices of points (CF-3) and mentally rotate shapes (S-1) after the training with videogames. The more complex the environment of the game (i.e. 3D Adventure), the more increase was found.

These results as a whole have significant spin-offs in terms of implications for educational software development. If we think at the growing educational potentiality of videogames in formal and informal education, being able to identify the optimal level of presence of an educational videogame could be crucial for adjusting the level of interaction to the appropriate learning goals.

On a second instance, assuming that the habitual experience with videogames is irrelevant in terms of presence could encourage to produce learning games without having to worry much about the steepness of the learning curve. Put in other words: provided the game is challenging both in terms of appearance and content, the cognitive feedback will be the roughly same regardless of the videogaming habits of the user.

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