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VIDEO GAME RESEARCH IN COGNITIVE AND EDUCATIONAL SCIENCES

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ABSTRACT

This work reviews several aspects of the growing research field interested in video games. First, the evolution of this media in the educational field is discussed. Three different fields interested in the cognitive impact playing of video games are reviewed: abilities and skills, attitudes and motivation, knowledge and content learning. However, most studies used video games as new experimental materials and tasks to contribute to their specific field (i.e. attention and perception), and not as a scientific object of interest *per se*. We claim that the research on video games is in need of a conceptual and methodological framework in which results and effects could be compared, interpreted and generalized. We argue that video games can have multiple effects on players and that these effects can be used as educational potentials. An empirically-based classification of games, depending on their potential effects for an educational purpose, is strongly needed. Likewise, a unified research paradigm and methodologies to carry on reliable research on video games has to be developed.

KEYWORDS: video games, simulation, education.

In the last decades, video games have been increasingly appealing not only as an entertainment for children and adults, but also as an object of interest in academic research. A large body of studies investigated the potential of information technology as tools for learning, and particularly of games specifically designed for educational purposes. Recently, a growing interest has appeared for the potential of mainstream games in education (in or out of the classroom). The basic claim of this line of research is that videogames may have beneficial educational impacts (Prensky, 2005), but few empirical findings reinforce this assumption.

On the other hand, psychology and cognitive sciences research have investigated the effect of video games on the players, following two directions: A first body of research aims at measuring the effect of playing video-games on cognitive abilities (perception, visual attention) and on development and personality (particularly on aggressive behaviors). A second body of research

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appeared recently within the theoretical framework of the multimedia learning community, in which content-based video games are considered as a particular interactive multimedia instructional material. In both cases, the video game is used as a particular task or material but its specificities are not taken into consideration. The effects of playing video games on cognitive and perceptual abilities, emotional responses and knowledge acquisition emerged in the literature, but they remain very disparate and inconsistent. Moreover, despite formal differences, the psychology research never compared the effects of different types of games on the developed assessments. This paper will review researches from different fields of cognitive studies involving video games in order to show the actual interests, but also the remaining lack of common paradigms.

Understanding the effects of playing video games

A problem with video game research, as often with information technologies, is the quick evolution of the media over the years. Video game research is only a few decades old but meanwhile its object has changed a lot. As Kirriemuir & McFarlane (2004) reminded, it is hard to compare an early text-based adventure game with next generation high-definition first-person shooters. Some constitutive rules of games and their ability to catch our attention completely, called "immersion" (MacMahan, 2003), can remain comparable over the ages. But the games that people play today have diversified and evolved in numerous directions. The change from penny arcade video games to networked personal consoles and home computers modified our relation to virtual play. Advances in game design and ergonomics also made game designers adapt their products. The market evolved from a limited and specialised phenomenon to mass market strategies. The way people play has changed, and is still changing, an example is the interest for mobile and casual gaming, or alternate-reality gaming (McGonigal, 2007). Therefore, if past research determined the potential effects and use of video games we still need to understand what in a game can have an influence, and what can be done to use a game in a given way. If games can change the players this change could be targeted on serious purposes, like educational ones.

Video games designed for learning

Games at large, without computers, have always been strongly connected to learning and education. Today, the literature about traditional games for education rarefies in favour of its digital child. The potential of video games for education meets agreement of most scholars, as evidenced by several works on the topic (Egenfeldt-Nielsen, 2005; Frété, 2002; Prensky, 2001).

From edutainement to the potential of mainstram games

Educational video games started to be developed relatively early in the computer science history. The obvious fascination of games and the power of computers to handle rules, interactions and feedbacks led to a growing interest. In the seventies, educational researchers and game developers started to investigate the potential of video games for education. The approach was to develop games that could teach contents or specific skills. In the eighties, the genres started to diversify (Willis, Hovey, & Hovey, 1987). Educational adventure games began to

spread ("Snooper Troops"® in 1982, for problem solving or "Where in the world is Carmen SanDiego"® in 1985 for geography). At the same time, the later called "edutainment" titles came out. Based on behaviourist approaches, these games alternate educational challenges and basic reinforcements (reward or punishment feedbacks). The player is assumed to learn through repetition of exercises presented to the learner–player in a progressive way. With the video game market growing through the eighties, the edutainment genre became dominant in the educational video game world and pushed other types out of the market. Egenfeldt-Nielsen (2005) argues that this growth was driven by business and market interests rather than by cognitive or educational principles. Therefore, in the nineties, educational games progressively loss their appeal. In particular, the remaining edutainment titles are now mostly targeted at young and pre-school children.

Recently, the education research community considered the educational potential of video games with a renewed interest (Egenfeldt-Nielsen, 2005; Gee, 2003; Prensky, 2001). In a sense, the decay of edutainment titles left room for researchers to reveal the need of thoughtful and innovative educational games. Nevertheless, the academic interest evolved and adopts today a different approach. Instead of developing specific games for specific learning purposes, it investigates the potential of mainstream games for education (Kirriemuir & McFarlane, 2004). They show that games developed at first solely for entertainment purposes may provide unexpected educational potentials. From analysing mainstream video games, Gee (2003) picked out 36 principles of learning which, he argues, are build into good video games. These principles, such as multiple routes to progress or the distribution of knowledge among artefacts, are not new to teachers but could inspire education and reinforce contemporary learning theories. They also illustrate quite strongly the complexity of what any video game can bring to the player. In the same vein, Gentile & Gentile (2005) demonstrate how several well recognised learning techniques are present in violent video games.

Video games at school

Over the last decade, educational boards gradually realised the importance of computer literacy and informational technologies for contemporary education. A number of studies have been commissioned, and video games have not be left apart. McFarlane, Sparrowhawk, & Heald (2002) led a large study in twelve primary and secondary schools of the United Kingdom. The goal was to collect data on the presence and use of video games in education. Teachers, parents and pupils were involved in the study and several types of games were evaluated for their use in classrooms. Their main conclusions go strongly in favour of a potential for mainstream video games in education, and furthermore in classroom environments. Video games embedded in larger educational activities can be very powerful to involve children. Since games are also played at home, they could bridge the gap between home and school. Nevertheless, not all genres of games are concerned, and their role should be to support learning activities organized by the teacher. The authors address some issues like the need of accuracy in content: consistency with reality, correct simulations of phenomenon and accuracy of

historical facts. Efficient information from the game developers should also be available for the interested teachers. Knowing more exactly what is involved in the game; which contents are presented and how it can affect the player would help the teachers to integrate video games in their classroom. As noticed by Larose, Bédard, Grenon, & Palm (2005), games not produced as didactical software and calibrated for school purposes will hardly be adopted by teacher who will not see their potential usefulness. Understanding precisely the effects and potentials of mainstream games is currently needed in order to be able to transfer them for classroom use.

To sum up, McFarlane et al. (2002) distinguish three potential uses of video games in a classroom environment:

- *Developing skills and abilities*: from specific skills like deductive reasoning or memorization, to more contextual ones like co-operation and communication skills, the authors draw up a list of potential developments through games, with integration in a classroom setting. Video games change cognitive abilities and skills.
- *A stimulus for learning*: the game sessions can be used as a starting point for other activities such as creative writing or charts analysis. Video games influence affective and motivational aspects.
- *Content related learning*: this is possible but can be very peripheral. Moreover, content in the game can be presented in a very different way as it usually is in the classroom. Simulations remain the games with the greatest potential to directly teach content, but the accuracy of their driving models has to be irreproachable and learning activities still need to be designed. Games allow direct knowledge and content learning.

Different types of games

Any game will not necessary be suited to the teacher's objective. To choose the good one, it is necessary to classify games in a number of categories. Kirriemuir & McFarlane (2004) underline the absence of a standard categorisation and chose, like Orwant (2000), the Herz system (1997), in eight categories (action, adventure, fighting, puzzle, role-playing, simulations, sports and strategy games). Other works on the educational potential of video games are also categorising video games (Egenfeldt-Nielsen, 2005; Fréte, 2002; McFarlane et al., 2002; Prensky, 2001, 2005). The classifications employed vary widely in the number of categories and in their ability to differentiate games. Nevertheless, an underlying idea is common to all categorizations: the potential of video games varies qualitatively and quantitatively according to the type of games. A classification of video games according to their educational potential is awaited by professionals. As a first step, Larose et al. (2005) suggest an analysis of a wide distribution of games in order to make it possible for teacher to efficiently use them as tools in the classroom. Kirriemuir & McFarlane (2004) ask for an involvement of the game development industry to better fit in the multiple constrains of educational context. Up to now, education researchers and practitioners are still waiting for a reliable

and relevant classification of video games according to their potential impact regarding specific learning objectives.

Psychology and cognitive research on video games

Studying the effects of video games, lead to ask what dimensions of the game experience can affect cognitive abilities. Gentile (2005) defined four independent dimensions: amount, content, form and mechanics. The *amount* refers to the time spent playing video games and the habits of play. This leads to considerations about video game addiction. *Content*, refers to effects of the messages carried by the video games as a media. Studies about games having an effect on behaviours, skills and attitudes typically enter in this dimension. *Effects*, can be studied as negative, like violence and aggressiveness change, or positive like health promotion (Lieberman, 2001). *Form*, refers to a kind of knowledge of the media. For example, the constant need to scan the screen in action games could improve some visual attention skills. Realism issues are also contained in this dimension. *Mechanics* refers to mechanical input-output devices used. Immersion in the game would be different depending on the interface, the results in effects or learning could follow. Nevertheless, finer definitions can always be found. Inside of what Gentile (2005; Gentile & Stone, 2005) call content, one could differentiate the effects on several supplementary dimensions, already enumerated from educational research needs:

- Cognitive abilities and skills: work of researchers in perception and attention (Green & Bavelier, 2003, 2006; Greenfield, deWinstanley, Kilpatrick, & Kaye, 1994; Kearney, 2005)
- Affective and motivational aspects: Like the current works on aggressiveness and hostility (Anderson & Bushman, 2001; Durkin & Barber, 2002) or motivational issues (Mortensen, 2003; Yee, 2005).
- Knowledge and content learning: addressed by educational psychology studies (Mayer, Dow, & Mayer, 2003; Moreno & Mayer, 2005; Sims & Mayer, 2002).

Cognitive abilities and skills

In five experiments, Green & Bavelier (2003) assessed regular action video game players with several tasks such as the flanker compatibility, enumeration performance, attention over space and attention over time. Regular action video game players always performed better at these tests than non video game players. The increase of performance seems induced by the activity of playing an action video game, since in another experiment, a control group played "tetris"® and the experimental group played "medal of honor"® for ten days (one hour a day). Afterwards, the experimental group performed better at several of the same tasks than the control group. Nevertheless, in other studies, "tetris"® was used as the experimental setting, and changes were observed. In two experiments, Okagagi & Frensch (1994) asked students to play "tetris"® for half an hour a day during twelve days. Their improvement at six spatial performance assessments were measured, four of these tests were taken from the standardized French, Ekstrom, & Price (1963) battery. The results indicated improvement of mental

rotation time and spatial visualization for “tetris”® players. Important gender differences, favouring males, were also obtained on complex mental rotation tasks. More recently, Sims & Mayer (2002) demonstrated the specificity of spatial expertise obtained by playing video games like “tetris”®. In their setting, experienced “tetris”® players outperformed non-players at mental rotation tasks, but not at a series of other spatial ability tests. In a second experiment, female students played twelve one hour sessions of “tetris”® and showed the same gain than control group on the spatial ability tests. They concluded that if a spatial expertise can be gained by playing “tetris”®, it is likely very domain specific and could concern only specific representations, (here “tetris”® shapes).

Using different video games (“marble madness”® for the experimental group and “conjecture”® for control), Subrahmanyam (1994) reported some improvements in the dynamic spatial reasoning abilities of eleven years old children. The genre was an issue as boys benefited more from the video game than girls. But initial visual ability turned out to determine the influence of the playing sessions: participants highly skilled in spatial reasoning showed no gain with the action game or the control game. However, low skilled participants who played the action game for three sessions of forty-five minutes significantly improved at the post test. The list of studies assessing different cognitive aspects of participants is still long. The methodologies are rather comparable, they either compare regular video game player to non video game players on several tests, or they establish a pre test-post test paradigm and ask participants to play in between. Depending on studies, control groups do not play or sometimes play a game considered to have no influence. However, Green & Bavelier (2003) asked their control group to play “tetris”® and obtained no effect with them, while Sims & Mayer (2002) found effects of playing “tetris”®, both assessed perceptual abilities.

If the methodologies themselves are solid, the applications differ. The games and populations are rarely the same from a study to another and the duration of playing sessions are also variable. Moreover, the conclusions are not always in favour of an improvement of the capacity for video game players. Genre and initial abilities could be an issue but also certainly the type of video game involved in the experiment. We listed here researches about perceptive abilities; however other abilities have to be integrated. Meta-cognitive abilities, for example, could play a role (Veenman, 2005), as problem-solving tasks have been investigated (Dempsey, Rasmussen, & Lucassen, 1996). This growing body of research asks what characteristics a game needs to be a factor in the change of cognitive and perceptual abilities. And this leads to the inverse interrogation, what can a given game potentially change in the player’s cognitive and perceptual abilities?

Attitudes, aggressiveness and motivation

Studies investigating affect, mood, and even behavioural change such as the influence of video games on aggressiveness and hostility have been numerous. Recently the American psychological association issued a resolution on violence in video games and interactive media (Williams & Skoric, 2005), recognizing multiple negative influence of these media on players, especially younger ones.

This can be a very important issue since in 2001, 64% of video games rated " suitable for everyone" involved intentional violence (Thompson & Hanninger, 2001). The social learning theory would predict a promotion of aggressive tendencies through violent video games (Bandura, 1986). But on the other hand, the catharsis theory would predict a channelling of latent aggression in the player (Feshbach & Singer, 1971), and therefore video games would have a positive effect on this dimension. Griffiths (1999) reviews twenty-four studies using different methodologies to examine the relationship between video games and aggression (self-reported aggressiveness, experimental or observational studies). Only studies using observation of very young children's free play concluded to a potential increase of aggressive behaviours. The author also underlines the many different types of video games and the difficulty to define "violence" and "aggressiveness", especially with the evolution of technical capabilities over the years. Another larger meta-analysis across 54 studies, suggests that playing violent video games increases aggressive behaviour and several hostility factors in children and young adults, male or females (Anderson & Bushman, 2001). The work of Anderson (2000) moderate the results since initial hostility trait may influence the effect of playing violent video games, but also found negative effect on academic performance of game play in general (not only violent video games). Gentile (2004) also showed that adolescents more exposed to video game violence were more hostile, got into more arguments and fights and performed more poorly in school. In a more recent meta-analysis on the effects of violent video games, Ferguson (2007) shows a publication bias (studies showing effects or not can rarely be published in the same journals). Moreover, studies using less standardized measures of aggression showed more effects. It was concluded that the current literature on the subject is not strong and reliable enough to show an effect of violent video games on aggressive behaviour.

Goldstein (2005) critically reviews the literature about video games and aggression. He asks why and how people play violent video games as no one is forced to, except in a laboratory. The effects of video games on emotional aspects are clearer day by day. The studies presented here refer mostly to aggressiveness and hostility changes, but motivational aspects and investment are also to take into account. Like motivation of play (Yee, 2005), video game addiction (Griffiths & Hunt, 1998), the flow of optimal experience (Csikszentmihalyi, 1992; Kiili, 2005), feeling of presence and immersion (Lombard & Ditton, 2000; Witmer & Singer, 1998) or emotional appraisal (Van Reekum et al., 2004). What makes someone play and keep playing and how it influences motivations and investment for other activities, is a strong question asked today.

Knowledge and content learning

Psychological research on learning and comprehension from multimedia contents is an active research domain (Mayer, 2005; Tversky, Bauer-Morrison, & Bétrancourt, 2000). Recently multimedia research has begun to focus on more interactive devices, though the attempts to investigate the effects of the video game media are scarce. Moreno & Mayer (2005) asked college students to play an

interactive multimedia game designed to teach botanic. Different learning conditions were proposed and the study underlined the importance of guidance for retention and transfer of learned knowledge. Positive aspects of interactivity were found but on specific conditions. The game used was a quizz-like multimedia simulation and could more be compared to an edutainment product than an actual mainstream video game.

In order to study the learning potential of games, Rieber, Tzeng & Tribble (2004) used a computer-based interactive simulation to teach Newton laws to adults. Delivery features like the modality of feedbacks (animated graphics or numeric displays) or the presence of brief multimedia explanation were experimentally investigated. Results are in favour of graphical feedbacks and explanations to improve comprehension and retention of the material. Rieber & Matzko (2001) present several simulations as activities to learn physics. They discuss the importance of "serious play" as a design goal for active and meaningful engagement by the students. They show that without multimedia explanations, the content from the game is not remembered. If these studies are very valuable and add to the understanding of the field, they are not really using games. They start from the multimedia learning field, and often add interactivity as a new dimension. Video games developed for educational purpose or mainstream games are not simply interactive multimedia explanations.

Roadmap for the research on cognitive effects of video games

In summary, we identified three trends in the cognitive research on video games according to the dimensions beyond the scope: cognitive abilities and skills, affective and motivational aspects, knowledge and content learning. In most of these studies, video games are considered as promising new materials or tasks that can foster knowledge of the dimension under investigation. However, they do not consider video games as scientific objects of interest and consequently, they do not intend to contribute to the general understanding of the cognitive impact of video games at large. Moreover, the research that tries to correlate video game play and specific abilities and skills (i.e. attentional and visuo-spatial abilities) is facing a methodological problem, since it is difficult to disentangle which affects the other: Is the specific ability promoted through extensive play, or conversely, is the extensive play caused by the player being high in this ability?

To circumvent this bottleneck, we propose a roadmap for the research on the cognitive impact of video games. Up to now, most of the literature has investigated to what extent a given ability, skill, knowledge, is influenced by playing video games. We propose the opposite approach: On the basis of previous research, we should identify the cognitive, affective and representational impact of a given video game. Two major moves are necessary:

First, the research needs a clear state of the art on the cognitive and affective impacts of video game, in order to identify which game has been shown to act on each specific dimension. Second, the findings should then be empirically assessed through large-scales statistical studies and small-scale experiments. The large-scales studies will consist in investigating the level of abilities of regular

players of the selected games on the specific dimensions, to assess the existence of a correlative link. The small-scale experiments will evaluate the evolution of a given ability, skill or knowledge of participants that are asked to play the game regularly.

We claim that the resulting multidimensional categorisation will constitute a framework for systematically investigating which type of game may have a cognitive effect that can promote the development of abilities, skill or knowledge. As Gentile (2005) claimed, one clear improvement will be to move beyond the public and scientific dichotomous view on video games, seen as *good* or *bad*. Of course, this categorization would not provide a "ready-to-use" manual for using video games in school. After the cognitive research assesses the actual impact on processes and representations, the education research will still have to identify the best educational setting to turn a potential into an actual effect.

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