



The Representation of Virtual Reality in Education

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Students' opinions about the opportunities and the implications of VR in instruction were investigated by administering a questionnaire to humanities and engineering undergraduates. The questionnaire invited participants to rate a series of statements concerning motivation and emotion, skills, cognitive styles, benefits and learning outcomes associated with the use of VR in education. The representation which emerged was internally consistent and articulated into specific dimensions. It was not affected by gender, by the previous use of VR software, or by the knowledge of the main topics concerning the introduction of IT in instruction. Also the direct participation in a training session based on an immersive VR experience did not influence such a representation, which was partially modulated by the kind of course attended by students.

Keywords: virtual reality; representation; attitudes toward computer; technical instruction; post secondary education.

Introduction

Opportunities of Virtual Reality in instruction

Virtual Reality (VR) offers a large number of possibilities in instruction (Helsel, 1992; Wexelblat, 1993). VR helps students both to experience directly some physical properties of objects and events and to realise the actual implications of such properties. VR favours also the discovery of features which are often, in traditional educational tools, perceptually 'hidden' because it permits users to look at elements which cannot be seen (Osberg, 1995; Pantelidis, 1993); on the other hand, VR prompts students to conceptualise experience at an abstract level (Antonietti & Cantoia, 2000). Moreover, VR allows users to change one's

point of view in a continuous and flexible manner by accessing new, unusual perspectives (Ferrington & Loge, 1992), or to make transformations that would otherwise be impossible in the real world (Larijani, 1994). Furthermore, VR permits one to vary the values of some given variables in order to verify the consequences of these changes. In other words, VR provides a field where students may attempt to carry out 'mental proofs', and also free and imaginative elaboration of the inputs (Austakalnis & Blatner, 1992; Kruger, 1991). Finally, VR helps learners to realise some critical issues involved in knowledge construction since they can grasp important epistemological implications (Mantovani, 1996); for instance, VR experiences induce students to assume spontaneously a meta-perspective, namely, to think not to 'what' they face to, but to 'why' or 'how' something is in front of them (Antonietti & Cantoia, 2000).

The importance of the representation of VR

The educational opportunities of VR need to be recognised by students in order to become effective. This leads us to consider the representation that students have of what VR involves when it is employed in instruction. However, whereas students' general attitudes toward the computer have been extensively investigated (e.g., Francis, 1993; Gardner, Dukes & Discenza, 1993; Smith, Caputi & Rawstorne, 2000), little is known about students' opinions about the impact that the computer can have on learning processes (Perry & Perry, 1998; Wilson & Whitlock, 1998); and as yet no data is available about what students think about the specific impact of VR in instruction.

The first goal of this study was to analyse students' representation of some psychological correlates which are usually associated with the use of VR for educational aims. The second purpose was to assess whether such a representation was affected by gender, a factor that literature suggests to be a relevant variable in studying attitudes toward computer (e.g., Colley, Gale & Harris, 1994; Shashaani, 1993). Thirdly, we were interested in identifying possible links between the representation considered here and the kind of study attended. Furthermore, the study was aimed at verifying whether the previous use of any VR package and/or the competence acquired about instructional issues involved in computer use influence the representation. Finally, we wondered whether the direct experience with a VR educational tool can modify the representation of VR in education. As far as the last question is concerned, we engaged a subsample of students in an instructional session devised to teach, by means of a VR package allowing an immersion into a virtual workshop, some principles of machining.

An instrument to study the representation of VR in education

In order to study what students think about the use of VR in instruction, a questionnaire was devised. It consisted of 24 items concerning various psychological aspects. In each item a statement was reported. The respondent was asked to rate on a 5-point scale (1 = minimum; 5 = maximum) his/her agreement about what was expressed in each

statement. The items of the questionnaire are listed in Table 1: the first column reports the number of the item (in the table items are listed in an order which corresponds to the decreasing values of the means recorded, whereas in the questionnaire they were listed in a different order corresponding to the number of the items); the second column reports the statement (the subject of the sentence was always 'Virtual Reality . . .').

Items were focused on the psychological correlates of using VR in instruction and concerned these issues: motivational and emotional aspects of learning (e.g., attraction, involvement, boredom, tiredness), behaviour during the learning process (active participation, effort), mental abilities required (attention, language, motor control), style of thinking preferred (intuition, visualisation, reflection), cognitive benefits and learning results (better understanding, memorisation, application, immediate feedback, overall view), metacognition (planning). Statements were designed by following two approaches. Firstly, the review of literature about VR in instruction suggested some relevant topics to be included in the questionnaire: claims about the opportunities that VR opens in education and alleged risks, skills and processes involved, learning outcomes, and so on were converted into statements. Secondly, five secondary-school teachers employing VR in their professional activity were asked to list what, in their opinion, characterises the use of VR in education. Lists produced following the first and the second approaches were collapsed into a general

Table 1. Mean scores and standard deviations of all the items of the Questionnaire listed in decreasing order

#	ITEMS: 'VR . . .'	M	SD
20	IS ATTRACTIVE	4.37	0.97
24	ALLOWS AN IMMEDIATE CHECK OF WHAT HAS BEEN STUDIED	3.99	1.04
5	FACILITATES PERSONS WHO HAVE A VISUAL THINKING STYLE	3.96	1.16
1	INDUCES PERSONS TO BE ACTIVE	3.90	0.95
8	HELPS PERSONS TO HAVE A GLOBAL OVERVIEW	3.87	0.98
14	MAKES THE COMPREHENSION EASIER	3.74	0.94
10	MAKES NOTION APPLICATION EASIER	3.57	1.06
16	REQUIRES CONCENTRATION	3.57	1.08
12	MAKES THE MEMORIZATION EASIER	3.43	0.99
11	ALLOWS TO LEARN FAST	3.42	0.95
13	REQUIRES TO PLAN ACTIONS	3.31	1.06
18	FACILITATES PERSONS WHO HAVE AN INTUITIVE THINKING STYLE	3.24	1.12
9	ALLOWS TO LEARN WITH NO EFFORT AND/OR IN AN IMPLICIT WAY	3.17	1.08
6	IS SUITABLE FOR PERSONS WHO ARE BORED IN A SHORT TIME	3.14	1.32
7	FACILITATES PERSONS LACKING OF LINGUISTIC ABILITIES	3.01	1.23
21	FACILITATES PERSONS WHO TEND TO THINK SCHEMATICALLY	2.99	1.01
23	FACILITATES PERSONS WHO HAVE QUICK REFLEXES	2.68	1.08
17	IS SUITABLE FOR LOGIC PERSONS	2.68	0.92
22	REQUIRES MANUAL ABILITIES	2.55	1.19
2	IS SUITABLE FOR THOUGHTFUL PERSONS	2.54	0.96
3	IS TIRING	2.49	1.21
19	MAY BE TOO INVOLVING	2.41	1.21
15	MAY BE CONFUSING	2.19	1.08
4	IS NOT SUITABLE FOR PRECISE PERSONS	2.02	1.14

list by avoiding repetition of the same issues and by integrating similar issues into a unique statement.

In the questionnaire the list of statements to be endorsed was preceded by a brief introduction explaining the aim of the instrument (that is, studying what persons think about the use of VR in education) and reporting the instructions for completion.

The virtual workshop

The instructional session employed in this study was based on a VR prototypal system devised to teach the utilisation of machine tools. The prototypal system consisted of an environment, a virtual workshop, which contained a traditional centre lathe and a milling machine, and of a hypermedia environment providing technical information and didactic instructions; a third environment (tutor) had the function of introducing the student into the system and of allowing them to choose among some proposed alternatives according to the preferred type of exercise and learning modality.

The VR environment was designed to enable students to learn about the architecture of the machines (declarative knowledge) and their use (procedural knowledge) within a realistic situation, performing practical operations, both physical (i.e., piece positioning on machine tool and cutting tool movement) and conceptual (i.e., choice of cutting tool from the virtual store, choice of cutting speed). The virtual machines were planned to satisfy some requirements mentioned above. They were highly interactive because they could work only if students performed the appropriate operations; each performed operation was followed by feedback about its correctness. Furthermore, on-line assessment and direct evaluation were provided because comments about each step of the procedure were given. Comments consisted either of error messages and hints at consulting the relevant section of the hypermedia or of prompts to carry out the next operation. Learning paths were personalised both since students were free to operate on the machine according to different working styles and since they were allowed to begin from the exploration of the virtual prototype or from the navigation of hypermedia. This should also facilitate integration of practical and conceptual ways of learning. During this study we focused only on the turning lathe.

The virtual lathe was constituted by a set of components (structures, piece supports, parts for the information transfer, and control) that received power, data, and materials with the goal to modify their physical characteristic by a sequence of operations. The machine presented some components that were in relative motion and therefore it was necessary to define their own kinetics characteristics and their movement synchronisation according to the specific operation to be carried out.

The hypermedia environment represented the knowledge store/manager of the system. It allowed the student to learn through texts, pictures, movies, graphical simulations, and VR or real situation demos. It was divided into three parts: glossary, hypertext, and simulation. The student could access the hypermedia environment on his/her request; the structure of the student-computer interaction was open-ended. Five different kinds of

lesson were implemented in the system: theoretical, demonstration, guided practising, free practising, and examination.

Improvements in learning with the Virtual Workshop

The instructional efficacy of the virtual workshop was tested extensively in some experiments (Antonietti, Imperio, Rasi & Sacco, in press) which showed that the virtual lathe can be used to teach what a lathe is and how such a machine works. The virtual workshop allowed students to understand the essential features of the lathe and to update or to restructure their initial knowledge of this machine. The outcomes showed that the virtual lathe experience enabled students to construct in their mind a whole model of the machine in which elements acquired via direct experience and notion presentation were integrated.

The trends recorded suggested that in naive students learning is enhanced when the exploration of the virtual lathe precedes the presentation of hypermedia information; while, for expert students it is better to begin to inspect hypermedia and then to navigate the virtual environment.

It was argued that the construction of a mental model requires that some separate elements are integrated into a whole structure (Gentner & Stevens, 1983; Johnson-Laird, 1983). Applying this perspective to the case of learning what a lathe is and what it is for, we assumed that understanding of such a machine requires students to be able to represent its parts correctly assembled and to identify their functional roles.

In the construction of a mental model some elements play the role of pivot-cues or of 'pegs' to which the other elements can be linked. Presumably, different levels of familiarity with the contents to be learned induce people to privilege a particular kind of such 'pegs'. Naive students prefer to begin by fixing in their mind some concrete 'pegs' derived by motor-perceptual experience; expert students prefer to improve their preliminary knowledge first by activating conceptual 'pegs' and then by relating to these elements new elements they catch by direct experience through action.

A study on the representation of VR

Participants

A total of 110 undergraduates (60 male and 50 female) volunteered in the study. Participants ranged in age between 22 and 28 y. They were not paid nor received course credits.

Undergraduates were divided into two groups according to the kind of faculty they attended: 58 humanities students (Philosophy, Literature, Foreign Languages, Pedagogy, Psychology) and 52 technical-scientific students (Engineering). Within each group individuals were randomly assigned either to the 'No VR experience' or to the 'VR experience' condition so that two subsamples of equal size were constituted.

Procedure

Students were asked to participate in an investigation about the use of computers in education. Participants assigned to the 'No VR experience' condition were told that they should fill out a questionnaire; participants assigned to the 'VR experience' condition were told that they should be involved in an about 1-hour learning session in which they would use a VR environment aimed at teaching some core concepts of machining. In all cases students were told that the questionnaire was anonymous and that there were no time limits to fill it out.

The questionnaire was administered to 'No VR experience' students in the university campus before the beginning of a class. These students were asked to tell if they had previously used any kind of VR software.

Students assigned to the 'VR experience' condition filled out the questionnaire at the end of the training session in the virtual workshop. The training consisted of the following phases:

Warm up: basic instructions for navigating the virtual environment were provided and exemplified; then students were trained in exploring the virtual environment by allowing them to navigate ad libitum the virtual workshop.

Assigned task: students were asked to employ the virtual lathe included in the virtual workshop to carry out given operations. They could use the hypertext about the lathe in order to achieve information about how to perform the task.

Main features of the representation of VR

Patterns of responses

Table 1 reports mean rates computed in each item considering the whole sample. The inspection of the table shows that means are distributed along a relatively wide range of values. It is worth noticing also that in each item the distribution of responses covered all the range of the possible rates (from 1 to 5). Thus, items of the questionnaire seemed to be adequately discriminative.

The overall picture that emerges is encouraging: in fact, negative items – that is, items reporting statements which describe possible limits and risks of VR – had the lowest mean values. Furthermore, the highest rates concerned properties of VR which are not trivial: for example, students appreciated very much the opportunity that VR allows to check immediately what is learned, to acquire a global vision, to facilitate understanding, or to apply the notions assimilated.

A factor analysis was carried out by considering all items and by applying the principal component model. Cattell's Scree test suggested the extraction of five factors. After a Varimax rotation, the matrix reported in Table 2 was obtained. Factors can be interpreted as follows:

Table 2. Factor analysis matrix after Varimax rotation

ITEM	FACTOR				
	1	2	3	4	5
MAKES THE COMPREHENSION EASIER	.77				
MAKES THE MEMORIZATION EASIER	.69				
MAKES NOTION APPLICATION EASIER	.68				
ALLOWS AN IMMEDIATE CHECK	.61				
IS ATTRACTIVE	.60				
INDUCES PERSONS TO BE ACTIVE	.55				
ALLOWS TO LEARN WITH NO EFFORT	.44				
HELPS PERSONS TO HAVE A GLOBAL OVERVIEW	.41				
MAY BE TOO INVOLVING		.60			
FACILITATES PERSONS WHO HAVE QUICK REFLEXES		.55			
FACILITATES PERSONS WHO HAVE AN INTUITIVE STYLE		.54			
REQUIRES CONCENTRATION		.53			
MAY BE CONFUSING		.50			
IS TIRING		.46			
FACILITATES PERSONS WHO HAVE A VISUAL STYLE		.44			
IS SUITABLE FOR THOUGHTFUL PERSONS			.66		
IS SUITABLE FOR LOGIC PERSONS			.63		
FACILITATES PERSONS WHO THINK SCHEMATICALLY			.62		
IS SUITABLE FOR PERSONS WHO ARE BORED				.60	
IS NOT SUITABLE FOR PRECISE PERSONS				.55	
FACILITATES PERSONS LACKING OF LINGUISTIC ABILITIES				.51	
REQUIRES MANUAL ABILITIES				.44	
REQUIRES TO PLAN ACTIONS					-.69
ALLOWS TO LEARN FAST					.68
Eigenvalue	3.71	2.90	2.04	1.67	1.33
Percentage of variance explained	16.05	12.07	8.49	6.96	5.55

- Factor 1 includes items concerning the cognitive outcomes of the learning process (comprehension, memorisation, global view, check, and application) and some motivational aspects.
- Factor 2 refers to a direct learning style (based on intuition, visualisation, quick reflexes) and to possible limits of such a style (e.g., confusion and excessive involvement).
- Factor 3 is loaded by items describing personal qualities associated to reflection and abstract thinking.
- Factor 4 can be labelled as ‘action approach’ since it is characterised by traits such as impatience, inaccuracy, manual skills.
- Factor 5 concerns an impulsive, not strategic approach.

Gender differences

Mean rates of each item were calculated separately for the male and the female subsamples. T-test revealed no significant differences due to gender.

Differences depending on the kind of course attended and on educational VR experience

Two-factor analyses of variance were carried out on each item of the questionnaire by assuming the kind of faculty attended (Humanities vs Technical-scientific) and the training with the virtual workshop ('No VR experience' vs 'VR experience') as independent variables. Table 3 reports mean rates recorded in each cell of the 2×2 factorial design and

Table 3. Mean scores (SD in parentheses) in Humanities and Engineering students under the NO VR and VR experience conditions and results of ANOVAs

ITEM	CONDITION				ANOVA <i>F</i>		
	HUMANITIES		ENGINEERING		FACULTY	VR	FACULTY EXPERIENCE X VR EXPERIENCE
	NO VR	VR	NO VR	VR			
IS NOT SUITABLE FOR PRECISE PERSONS	1.81 (0.98)	1.70 (1.07)	2.21 (1.20)	2.42 (1.25)	6.82 **	0.05	0.51
MAKES NOTION APPLI- CATION EASIER	3.19 (0.98)	3.33 (1.11)	4.00 (0.82)	3.83 (1.17)	11.20 ***	0.00	0.62
MAKES THE MEMORIZA- TION EASIER	3.30 (0.94)	2.85 (1.06)	3.86 (0.80)	3.75 (0.90)	16.91 ***	2.35	0.86
REQUIRES TO PLAN ACTIONS	3.10 (0.79)	3.15 (1.13)	3.21 (1.26)	3.87 (0.90)	4.54 *	3.23	2.36
MAKES THE COMPRE- HENSION EASIER	3.61 (0.84)	3.22 (1.12)	4.14 (0.75)	4.00 (0.78)	14.81 ***	2.46	0.53
IS ATTRACTIVE	4.52 (0.72)	3.85 (1.32)	4.78 (0.50)	4.30 (0.99)	4.00	10.68 ***	0.23
FACILITATES PERSONS WHO HAVE QUICK REFLEXES	3.00 (0.93)	2.96 (1.22)	2.68 (1.10)	1.96 (0.75)	11.55 ***	3.77	3.07
ALLOWS AN IMMEDIATE CHECK OF WHAT HAS BEEN STUDIED	3.39 (1.17)	4.18 (1.03)	4.18 (0.77)	4.33 (0.81)	6.32 *	6.50 *	2.96
IS SUITABLE FOR THOUGHTFUL PERSONS	2.45 (0.77)	2.67 (1.00)	2.28 (0.76)	2.79 (1.28)	0.01	3.86 *	0.63
IS SUITABLE FOR PERSONS WHO ARE BORED IN A SHORT TIME	3.58 (0.92)	2.81 (1.44)	3.28 (1.38)	2.79 (1.41)	0.41	6.47 *	0.30
MAY BE TOO INVOLVING	2.97 (1.08)	1.81 (0.83)	2.82 (1.30)	1.87 (1.15)	0.04	24.54 ***	0.24
FACILITATES PERSONS WHO TEND TO THINK SCHEMAT- ICALLY	2.74 (0.93)	3.22 (1.05)	2.78 (0.83)	3.30 (1.16)	0.09	6.74 *	0.00

* $p < .05$ ** $p < .01$ *** $p < .001$

the results of the ANOVAs (only if significant principal and/or interaction effects occurred).

Engineering students rated higher than humanities students the cognitive aspects of the learning results produced by VR: memorisation (respectively, $M = 3.81$, $SD = 0.84$; $M = 3.09$, $SD = 1.01$), comprehension ($M = 4.08$, $SD = 0.76$; $M = 3.43$, $SD = 0.99$), application of notions (respectively, $M = 3.92$, $SD = 0.98$; $M = 3.26$, $SD = 1.03$), immediate feedback ($M = 4.25$, $SD = 0.79$; $M = 3.76$, $SD = 1.17$). Engineering students evaluated higher than humanities students also planning ($M = 3.52$, $SD = 1.15$; $M = 3.12$, $SD = 0.96$) and imprecision ($M = 2.31$, $SD = 1.21$; $M = 1.76$, $SD = 1.01$). In contrast, humanities students scored higher than engineering students in the item 23 (quick reflexes) (respectively, $M = 2.98$, $SD = 1.07$; $M = 2.35$, $SD = 1.01$).

As far as the influence produced by the direct experience with the virtual workshop is concerned, we observed that it had the effect to increase, as compared to the 'No VR experience' condition, ratings about the immediate check (respectively, $M = 4.25$, $SD = 0.93$; $M = 3.76$, $SD = 1.07$), thoughtfulness ($M = 2.72$, $SD = 1.13$; $M = 2.37$, $SD = 0.76$), and schematic thinking ($M = 3.25$, $SD = 1.09$; $M = 2.76$, $SD = 0.87$), whereas it decreased ratings of involvement ($M = 1.84$, $SD = 0.99$; $M = 2.90$, $SD = 1.18$), attraction ($M = 4.06$, $SD = 1.19$; $M = 4.64$, $SD = 0.64$), and boredom ($M = 2.80$, $SD = 1.41$; $M = 3.44$, $SD = 1.16$).

The same 2×2 ANOVA model was applied to the factorial scores derived from the factorial analysis described above. Significant effects emerged only in scores of the first three factors. Engineering students obtained mean scores for Factor 1 higher than humanities students (respectively, $M = 0.31$, $SD = 0.88$; $M = -0.27$, $SD = 1.03$; $F_{1\ 106} = 10.05$, $p < .01$). 'No VR experience' students scored higher than 'VR experience' students on Factor 2 ($M = 0.29$, $SD = 1.01$; $M = -0.34$, $SD = 0.88$; $F_{1\ 106} = 12.63$, $p < .001$) whereas the opposite was true on Factor 3 ($M = -0.34$, $SD = 0.69$; $M = 0.39$, $SD = 1.16$; $F_{1\ 106} = 16.16$, $p < .001$).

Differences depending on the previous use of VR tools

Participants assigned to the 'No VR experience' condition were asked to say if they had previously used any VR tool. Thus, in this condition we could identify two subgroups of students: previous and no previous use of VR. No significant differences between these subgroups emerged by applying t-test at each item of the questionnaire.

Differences depending on expertise in educational application of VR

'No VR experience' humanities students were divided into two subgroups according to their previous participation/no participation to an academic course about the educational implications of information technologies (IT). T-test carried out for each item showed that mean rates separately computed for each subgroups were not significantly different. Only on item 22 students who attended the IT course scored significantly higher ($M = 2.87$,

SD = 0.96) than students who did not attend such a course ($M = 1.93$, $SD = 1.22$) ($t_{29} = -2.40$, $p < .05$).

Discussion

This study, focused on students' beliefs concerning the educational impact of VR, indicated that undergraduates identified a large number of opportunities stressed by theorists and researchers in the field of VR applied to instruction. It is worth noticing that not only the most blatant qualities of VR were recognised, but also more sophisticated, not self-evident issues were appreciated.

The representation studied here appeared to be internally articulated: a relatively clear factorial structure underlies the complex of evaluations that students were asked to express through the questionnaire. Consistent clusters of items emerged, suggesting that opinions investigated are coherent and organised into specific dimensions.

The representation at hand seems also to be stable. It is not affected by gender, by the previous use of VR software, or by the knowledge of the main cultural, pedagogical, and psychological topics concerning the introduction of IT in instruction. Also the direct participation to a training session focused on machining instruction and based on an immersive VR experience did not cause students to modify their thoughts about the role and the consequences of VR in education. The experience with the virtual lathe had only the effect to reduce ratings of the attractiveness and of the perception of involvement and to suggest that reflective and abstract thinking is required while learning through VR. Presumably, these changes depended on the specific features of the VR tool employed: the virtual lathe prototype, in fact, was heavily focused on the concepts to be learned and therefore involved a high load of mental processing; furthermore, it was characterised by an essential graphic with a low visual impact and without impressive sensory effects.

The most influencing factor appeared to be the kind of course attended by students, even though significant effects seemed to be restricted to a specific issue: engineering students appreciated more than humanities undergraduates the cognitive correlates of VR. This might depend on the fact that in technical-scientific disciplines conceptualisation plays a crucial role, so that learning difficulties are perceived particularly in that area; thus, engineering students are induced to believe that IT aids, such as VR tools, should produce relevant cognitive benefits.

The overall picture that emerges from the investigation is that students have a well-defined and deep-rooted conception about what VR can introduce in a learning process. This stresses the need to pay attention to what students think about the VR tools that they are asked to use. Such attention is important in order to verify whether what is relevant in the teachers' opinion is also relevant in the learners' opinion. The results of the study carried out suggest also that beliefs about the opportunities and the implications of VR in instruction are unlikely to change spontaneously or as a mere consequence of knowledge acquisition, practice, or experience. Rather, it appears that well-focused interventions are needed to lead students to reject inadequate conceptions about VR or to realise educational properties of VR of which they are not aware.

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