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Transfer of learning in virtual environments: a new challenge?

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Abstract The aim of all education is to apply what we learn in different contexts and to recognise and extend this learning to new situations. Virtual learning environments can be used to build skills. Recent research in cognitive psychology and education has shown that acquisitions are linked to the initial context. This provides a challenge for virtual reality in education or training. A brief overview of transfer issues highlights five main ideas: (1) the type of transfer enables the virtual environment (VE) to be classified according to what is learned; (2) the transfer process can create conditions within the VE to facilitate transfer of learning; (3) specific features of VR must match and comply with transfer of learning; (4) transfer can be used to assess a VE's effectiveness; and (5) future research on transfer of learning must examine the singular context of learning. This paper discusses how new perspectives in cognitive psychology influence and promote transfer of learning through the use of VEs.

Keywords Transfer of learning · Training · Virtual environment · Learning models

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1 Introduction

The transfer of learning concept is usually found in educational literature. Transfer is a key concept in learning theories since most education and training aspires to convey skills or knowledge (Haskell 2001). Indeed, transfer is crucial to all learning (Marini and Genereux 1995). The final purpose of education or training is to apply what we have learned in different contexts and to recognise and extend that learning to completely new situations.

When this transfer involves the field of work, authors use the expression "transfer of training". Transfer of training is defined as the extent of retention and application of knowledge, skills and attitudes from the training environment to the workplace environment (Pennington et al. 1995). From that perspective, acquisition of transferable knowledge and skills by workers, employees and managers is seen as a main component of a learning economy, resulting in a reduction in spending.

In education, "transfer of learning" relates to generating knowledge and information through education, which refers to the capacity to generalise and to learn by analogy (Subedi 2004). Transfer of learning is, broadly speaking, a process in which knowledge constructed in a particular context (source task) is used in a different context (target task) after being mobilised, recombined and/or adapted (Presseau and Frenay 2004). Although the transfer process is similar in both working and education domains, transfer of training should enable the target task to be performed, and transfer of learning should lead to a general base of knowledge.

This paper focuses on transfer of learning or training in a virtual environment. The use of virtual reality in computer simulations provides a significant approach to study this transfer, applied to both professional and educational domains. The issue of transfer has been widely studied in educational and cognitive psychology throughout this century. For a historical overview, see Cox (1997). However, as the available literature shows, interest has grown considerably for the topic over the past 20 years. In addition to many research articles, the transfer issue has been thoroughly analyzed and critically discussed in books and monographs (Singley and Anderson 1989; Detterman and Sternberg 1993; Analoui 1993; McKeough et al. 1995; Bracke 1998; De Corte 1999; Tardif 1999; Haskell 2001; Presseau and Frenay 2004). Even today, divergent points of view are found in the literature. Moreover, even researchers with similar or related theoretical backgrounds seem to have distinct opinions about the occurrence of transfer. The issue of transfer should lead researchers in educational technologies to examine five questions.

Some of these divergences are shown in how authors define the concept of transfer. Some seem to be interested in transfer content and thus focus on the types of knowledge, which could be transferred. When the approach looks at the accessibility of transfer, studies have highlighted what types of knowledge can be transferred and more particularly the way the knowledge base is organised. For those authors, the process of accessibility is not established in the same way for all types of knowledge. In VE, designers must consider types of transfer when they define the aim of their VE (Sect. 2).

However, for other authors, transfer is not a question of content. They are trying to identify both the process and the dynamics of transfer. Likewise, the have investigated transfer in problem solving contexts (Tardif 1999) and in analogical reasoning (Holyoak and Thagard 1995). In addition, a process-based approach to transfer has been investigated. In the latter, the dynamic process of understanding and the use of previous knowledge have been examined. Most cognitive psychologists consider the problem to be complex and several have emphasised the link between transfer phenomenon and information processing (Hatano and Greeno 1999). Studying the process of transfer should help determine the facilitating conditions of transfer in VE (Sect. 3).

A number of authors from different theoretical backgrounds have taken a negative position, more or less dismissing the possibility of transfer. For instance, some cognitive psychologists share Detterman's (1993) view that "The lesson learned from studies of transfer is that, if you want people to learn something, teach it to them. Don't teach them something else and expect them to figure out what you really want them to do". Indeed, transfer of learning is not spontaneous, but requires specific learning. In this case, it is called "informed transfer" (Gick and Holyoak 1987). We are not sure that this consideration is taken into account by VR designers. To ensure transfer-oriented training, making use of VR features appears to provide a promising path for VE development (Sect. 4).

Lave (1988), a proponent of the situated learning paradigm, also takes a stance against the very idea of transfer, basing her position on the grounds that knowledge and skills are context-bound. Contextual effects on learning have been demonstrated for various skills such as mathematics, language comprehension, memory tasks, problem solving and decision making. This theoretical perspective raises the question on the use of VE. If knowledge and skills are linked to their initial context (virtual simulation), how can a student use them in a real situation? Where does interest of building a virtual environment (VE) lie in terms of education or training? In fact, we can ask whether transfer of learning is not the main contradiction to be resolved in creating VEs.

Transfer can almost be taken as a way of measuring the effectiveness of learning. However, it is extremely difficult to track. Although part of the research carried out has been devoted to understanding it, transfer has remained an elusive concept. Transfer is not so much an instructional and learning technique as "a way of thinking, perceiving, and processing information" (Haskell 2001). More than a simple extension of learning, this process involves complex cognitive processing (Haskell 2001; Tardif 1999). Facilitating the transfer of learning from VE to the real world could well be the best way to prove how effective VEs are for learning or training (Sect. 5).

At this point, we have not entirely clarified the initial question, i.e. does transfer occur? Some authors like Lave (1988), Lave and Wenger (1991) have explained that knowledge is linked to the context of acquisition, and consequently is difficult to apply in different contexts. Anderson et al. (1996) criticised this situated learning perspective because they doubt whether transfer exists. In fact, one experimental study in VE did not indicate the presence of transfer (Kozak et al. 1993). However, others have shown its existence (Rose et al. 2000). So we maintain that future research on VE and learning should examine both the internal (prior knowledge or skill, emotions, etc.) and sufficiently immersing external contexts (visual properties of VE).

This brief overview of the issues involving transfer shows that a consensus is lacking. Therefore, our five sections present what we consider to be the five main ideas: (1) the type of transfer enables VEs to be classified according to what is learned; (2) the transfer process can create conditions within the VE to facilitate transfer of learning; (3) specific features of VR must match and comply with transfer of learning; (4) transfer can be used to assess a VE's effectiveness; and (5) future research on transfer of learning must investigate the singular context of learning.

2 What is learned in a virtual environment?

Reviewing the existing literature on virtual reality enables us to identify the various types of transfer and classify VEs. First, types of transfer are analysed from three theoretical standpoints, historically considered as three learning models: behaviourism, cognitivism and constructivism.

2.1 Models of learning

If we speak in very broad terms about trends in psychology, we can identify three fundamentally different ideas about the nature of learning and what the properties/nature of knowledge are. In other words, these approaches not only include a view of how transfer occurs, but also a view of what knowledge actually is (i.e. is knowledge given and absolute or constructed and relativistic? etc.). These three basic approaches or psychological theories are referred to as behaviourism, cognitivism and constructivism. The reason we refer to these learning models is that these theories have profoundly influenced the use of VEs. Obviously, theories go much further than what is presented in this paper. To reiterate, the important point for us and what we are focusing on here is that "changes" in the dominant psychological theories of learning have resulted in changes in the use of computers in education.

Put succinctly, behaviourists explain learning without referring to mental processes. We consider that the two important aspects of behaviouristic theories are (1) the learner is viewed as adapting to the environment and (2) the learning is seen largely as a passive process since the mental processing is not explicit. The learner responds to the "demands" of the environmental stimulus. Knowledge is viewed as being given and absolute (objective knowledge). The learning model, from the behaviouristic point of view, focuses on a new behavioural pattern being repeated until it becomes automatic. The cognitivist perspective "gets inside the learner's head" so to speak, in that its proponents have made mental processes the primary object of study and tried to discover and model the learner's mental processes during the learning process. In cognitivist theories, knowledge is viewed as symbolic, mental constructions in the minds of individuals, and learning becomes the process of committing these symbolic representations to memory, where they can be processed. This cognitivist view has emphasised the learner's "base of knowledge" and the role of declarative knowledge in transfer. However knowledge was still viewed as being given and absolute, as in the behaviouristic school of thought. Based on the thought process behind behaviour, changes in behaviour are observed principally by the use of declarative knowledge, but only as an indicator to what is going on in the learner's head. The constructivist school views knowledge as a constructed entity made by each and every learner through a learning process. Thus knowledge can not be transmitted from one person to the other; it has to be reconstructed by each person. In constructivism, knowledge is seen as relativistic (nothing is absolute, but varies with respect to time and space) and fallible (nothing can be taken for granted). Cognitive-oriented constructivist theories emphasise the abstraction on the part of each learner, which emerges from the action. This abstraction should be implicit to respond quickly in similar situations and should be explicit when domains change. In this view, knowledge is still very much a symbolic, mental representation in the mind of the individual. Based on the premise that we all construct our own perspective of the world based on our individual experience and schema, constructivism focuses on preparing the learner for problem solving in ambiguous situations.

2.2 Types of transfer and virtual environments

Several authors agree that accessibility is fundamental for transfer (Cormier 1987; Prawat 1989). When studies focus on accessibility of transfer, they show what types of knowledge are transferred and in particular, the organisation of the knowledge base (Brooks and Dansereau 1987; Brown et al. 1983; Prawat 1989). Thus the literature yields different types of transfers. In order to identify them, we shall take three conventional dichotomies indicating that transfer should be either vertical or horizontal, horizontal transfer should be near or far; and that transfer should be general or specific.

The first "product" (as opposed to "process") of transfer concerns the distinction between "vertical transfer" and "horizontal transfer". Vertical transfer means the use made directly by a subject with his or her own previous knowledge in building up new knowledge. Vertical transfer of skills and knowledge refers to the replication of the previously acquired knowledge and skills in all identical situations. This theory of transfer is based on the belief that previous learning facilitates new learning only to the extent that the new learning task contains elements identical to those in the previous task (Perkins and Salomon 1989). According to Misko (1995), quoted by Subedi 2004), this type of transfer often involves tasks that are procedural in nature, i.e. where the subject must act or do something. These tasks include a sequence of operational steps and the sequence is repeated every time the task is performed. When procedural learning is aimed for, the transfer rate of learning is usually high, but the learner is unlikely to adapt such skills and knowledge to a new environment and changing conditions (Subedi 2004). The vertical transfer consists in applying the same product to identical situations. For example, Volbracht et al. (1998) built a VE called “Citygame” to teach spatial orientation to children. The vertical transfer consisted here in recognising and applying this knowledge to the actual city itself. Horizontal transfer is the use of knowledge to solve a new problem or to carry out a new task, where the level of complexity does not matter (Tardif 1999). Webber et al. (2001) described a VE called “Baghera” to solve geometry problems for young students.

Transfer of learning has also been classified in terms of “near transfer” and “far transfer”. But from our point of view, “near transfer” also corresponds to “vertical transfer”. The terms are different but no conceptual distinction can be found. In contrast, horizontal transfer can require either near or far transfer. The latter refers to learning new skills or performing new tasks in situations that differ significantly from the original learning situation. Far transfer goes beyond simply applying or repeating procedures. It requires cognition and building of general or declarative knowledge to be adapted to changing situations or new environments (Misko 1995, 1999).

Although the importance of far transfer is acknowledged by almost all those responsible for training (Perkins and Salomon 1989), most training in industrial settings is more centred on procedural and near transfer than on declarative and far transfer (Subedi 2004). However, when used in education, the VE seems to focus on declarative and far transfer (Hietala and Niemirepo 1998; Webber et al. 2001; Popovici et al. 2005).

In summary, in near transfer there is a close connection between the learning situation and the application (behaviourist perspective). In far transfer, the distance between learning and application (or the second learning situation) is much greater. This distance can sometimes be measured or manipulated (Bassok and Holyoak 1993).

“General transfer” and “specific transfer” is another classical distinction. In this taxonomy, transfer is considered as “general” when the learning task is extended to many fields of knowledge and it is “specific” when learning and transfer tasks are close or in the related field (Cormier and Hagman 1987; Gick and Holyoak 1987; Perkins and Salomon 1988, 1989; Singley and Anderson 1989; and Tardif 1999). Other authors (Gick and Holyoak 1987; Haskell 2001) have also proposed the terms of “self-transfer” when the second task consists of a repetition of the first one, “near-transfer” when the two tasks are similar and “far-transfer” when the two tasks are different. For example, “EduAgent” is a virtual collaborative environment where students try to solve equations (Hietala and Niemirepo 1998). The VE aim is to develop collaborative competence that can be used in other academic fields (general transfer).

Finally, horizontal transfer depends on the distance between the initial context and the target context: transfer could be general or far as well as specific or next.

3 Transfer process: conditions to promote transfer in virtual environment

For cognitive psychologists, transfer is not just a question of content. They have also investigated transfer in contexts of problem solving (Brown et al. 1983; Tardif 1999; Bracke 1998; Presseau and Frenay 2004) and analogical reasoning (Gick and Holyoak 1987; Holyoak and Thagard 1995). In these cases, a process-based approach was used, more specifically focusing on the dynamic process of understanding and using prior knowledge. All these cognitive psychologists seem to consider the problem as complex and have highlighted the fact that transfer phenomena are rare, and difficult to observe and to teach (Brown et al.1983; Detterman 1993; Perkins and Salomon 1988).

From this perspective, the literature indicates that there is a “low road transfer” and a “high road transfer”. The low road transfer corresponds to an automatic transfer of skills learned by repetition, which depends on surface similarities between two tasks being detected (behaviourist perspective). The high road transfer consists in extracting knowledge in order to set it into a particular context or connect it with something that is already known in another context (Perkins and Salomon 1988, 1989). This dichotomy can be linked to the “information processing level” model. Craik and Lockhart (1972) argued that the more a piece of information is treated in depth, the better the retention will be. The concept of “depth encoding” distinguishes between sensorial encoding and semantic encoding. The first leaves a superficial mark in the memory, while the second leaves a deeper mark. We can articulate the two levels with the latter taxonomy: low road transfer consists in maintaining information in the working memory to facilitate vertical transfer and high road transfer would consist in making a mental effort of semantic encoding in the long-term memory by using previous knowledge. For near transfer, the low road (Perkins and Salomon 1989) is sufficient for automatic renderings and practising in a small range of situations (Anderson et al. 1996). For far transfer, however, the high road (Perkins and Salomon 1989), where decontextualisation and practice in a variety of different situations are important, is better. For learners, the paradox is whether to go for near transfer and to connect the range of situations, focusing on practice and automation, or to go for far transfer, searching for decontextualisation and variety.

What should a learner take with him from one learning situation to another? Perkins and Salomon (1989) wrote: “In general, the “what” (of transfer) might be a subroutine developed in the learning context but also useful in the transfer context, an overarching principle abstracted in the learning context but applicable in the transfer context, a piece of factual knowledge useful in both but in quite different ways, a learning strategy that becomes used in new domains, a cognitive style, or even a complex strategy of approaching new problems".

In our opinion, types of transfer and transfer processes should be gathered and linked to learning models. Related conditions influencing transfer of learning could subsequently be classified into three main psychological models of learning. This categorisation could determine the facilitating conditions of transfer.

3.1 Vertical and low road transfer

Vertical transfer and low road transfer can be combined. Indeed, using prior knowledge to build new knowledge corresponds to an automatic transfer of skills due to superficial similarities between two tasks. The process consists in recalling and maintaining information in the working memory to facilitate transfer. When the purpose of the training focuses on procedural learning, the transfer can be facilitated by automatic reflexes. In this case, the subject must learn by repetition, which is one characteristic of the behaviouristic perspective. In such a case, a computer system can generate a large number of similar simulations to provide environments, which will facilitate repetition in close context.

However, in both educational and training fields, acquisition of competence or skills remains an important aspect. It mobilises both procedural and declarative knowledge. In this case, the behaviouristic perspective is limited, firstly by the need for various and adapted behaviours and secondly because learners must be able to stand back from and analyze their action and performance.

3.2 Horizontal and high road

Horizontal transfer is the use of knowledge to solve a new problem or to perform a new task even with a high level of complexity. To respond, the learner has to extract knowledge in order to either abstract it from a particular context or connect it with something in another context. The process used corresponds to high road transfer. One of the specificities of this transfer could be the abstraction of semantic encoding. In this case, the subject's point of view is relevant for the learning. Learning consists in understanding the conditions of using procedural knowledge. For example, in a VE, such conditions can be explicitly displayed (blinking, transparency, etc.). In the cognitivist perspective, to facilitate transfer, the instructor or teacher has to indicate analogies between the training context and the assessment context, as seen in the "Citygame" (Volbracht et al. 1998). Procedural knowledge needs declarative knowledge about the tasks, contexts or metacognitive knowledge to be transferred. Informed transfer (Gick and Holyoak 1987) is needed during initial learning.

3.3 Horizontal and near transfer: the rich road

The third combination that can be described is the constructivism perspective. Near transfer of skills and knowledge refers to the replication of previously acquired knowledge and skills in any closely related situation.

As Subedi explained, quoting Perkins and Salomon (1996), "this theory of transfer is based on the belief that previous learning will facilitate new learning only to the extent that the new learning task contains similar elements to those in the previous task". Near transfer can be a horizontal transfer and require the rich road. Rich encoding of initial context means that learning depends on multiple types of encoding (images, kinesthetic sensations, verbal information, etc.) and facilitates transfer by the subject's adaptation. This constructivism perspective also holds that a high level of abstraction enhances the learner's skill. Similar elements are not necessarily recognised, but they are emerging and implicit. This is different from the cognitive model, in that, from the constructivist stance, teaching consists in organising a systematic, random variability for the student to perform (Mendelsohn 1996). In the VE, this variability of contexts is guaranteed by the entities' autonomy (Tisseau et al. 2001). The transfer process thus depends on several, varied processes (emotions, kinaesthetic information, and visual images), which are connected by their nature to the contexts (Craik and Lockhart 1972). So, near transfer can also be horizontal and require the rich road. "Virtualdive" is an example where children are immersed in a virtual underwater world where they can interact with different fish species. The hybrid-agent-based architecture allows children to adapt to various situations (horizontal transfer and rich road).

In Table 1, we present some examples of VE and identify which 'transfer processes could be associated with them.

4 Transfer and virtual reality features

The question of transfer can be studied by using virtual computer simulations. This approach has been applied to both professional and education fields. But, what is the interest of using virtual reality for transfer of learning? More generally speaking, what can be done with virtual reality?

To become progressively effective in a situation, the learner must learn by acting. Putting the learner into action can be expensive (in material terms) or risky (in human

Table 1 Examples of virtual environments and corresponding transfer processes

References	VE	Training or learning purpose	Learning conditions and VE properties	"low", "high" or "rich" transfer
VE for training				
Kozak et al. (1993)	Pick-and-place task	Task requires perception and motor skills	Repetition	Low
Buche et al. (2004)	MASCARET	Training for collaborative carrying out of procedures in a complex environment	Simulation exercise	Rich
			Critical tasks	
			Rare scenarios/conditions	
			To simplify and segment	
			Role of the parameters	
			To become familiar with the situation	
			To let mistakes be made and then use them	
Fréjus et al. (1997)	Virtual faucet	Diagnosis for industrial faucet repair	Interactions focus on diagnosis	High
			Students level to prepare the diagnostic intervention	
			Simulation exercise	
			Critical tasks	
			Rare scenarios/conditions	
VE for student				
Webber et al. (2001)	Baghera	Problem-solving in geometry	Interactions learners/teachers	High
			Demonstration	
			To put in situation	
			Critical tasks	
Hietala and Niemirepo (1998)	EduAgent	Mathematic equations	Collaboration	High
			Verbalisation	
VE for Children				
Popovici et al. (2004).	EVE	Reading	Discover	Rich
			To simplify and segment	
			Collaborative learning	
			Autonomy of agents	
			To become familiar with the situation	
			To let mistakes be made and then use them	
Mateas (1997)	Oz	Proposing story contents asking children to accomplish some tasks	Narrative based system	Low
			Simulation exercise	
			To become familiar with the situation	
			To let mistakes be made and then use them	
Hayes-Roth and VanGent (1997)	Virtual theatre	Drama	Narrative based system	High
			Simulation exercise	
			Critical tasks	
			Rare scenarios/conditions	
			Role of the parameters	
			To become familiar with the situation	
Johnson et al. (2000)	Quickworlds	Discovering a world by VR	Simulation exercise	Low
			To simplify and segment	

Table 1 continued

References	VE	Training or learning purpose	Learning conditions and VE properties	"low", "high" or "rich" transfer
Roussos et al. (1999)	NICE	Learning how to tend a garden	Collaborative learning	High
			Interactions between learners	
			Simulation exercise	
			Critical tasks	
			Rare scenarios/conditions	
			To simplify and segment	
			Role of the parameters	
			To become familiar with the situation	
			To let mistakes be made and then use them	
Bobick et al. (2000)	Kidsroom	A play room is transformed into an story-based world for play	Using images, lighting, sound, vision	Rich
			Objects react to children's choices	
			Simulation exercise	
			Rare scenarios/conditions	
			To simplify and segment	
			Role of the parameters	
			To become familiar with the situation	
			To let mistakes be made and then use them	
Robertson and Oberlander (2002)	Ghostwriter	Play multiple role in a story	To put in situation	Rich
			Critical tasks	
			Rare scenarios/conditions	
			To become familiar with the situation	
			To let mistakes be made and then use them	
Popovici et al. (2005)	Virtualdive	Discover and understand the wonderful silent underwater world	Hybrid agent interactions architecture	Rich
			Autonomy of agents	
			Simulation exercise	
			Critical tasks	
			Rare scenarios/conditions	
			To become familiar with the situation	
			To let mistakes be made and then use them	
Volbracht et al. (1998)	Citygame	Teaching spatial orientation to children	Simulation exercise	High
			Critical tasks	
			To simplify and segment	
			To become familiar with the situation	
			To let mistakes be made and then use them	

terms). This is the case when the purpose is to learn how to act and react when faced with accidents (non-compliance with rules of the road by drivers), unpredictable events (a child crosses a road unexpectedly) or malfunctioning (material difficulties or psychological breakdown during a risky intervention). This problem-solving skill in dynamic (uncertain, progressive and with strong time constraints) situations is particularly hard to deal with using a classical educational approach of case studies, establishing general rules or instructions related to expected scenarios. On the contrary, computer simulation makes it possible to immerse learners in a VE where they can try things, choose, take initiatives, fail and try again.

In education, VEs specially designed for children have also been developed to improve spatial orientation (Combry et al. 1996; Volbracht et al. 1998; Waller et al. 1998), make up or tell a story (Mateas 1997), take part in theatre (Hayes-Roth and Van Gent 1997), take care of a garden (Roussos et al. 1999) or a playroom for kids (Bobick et al. 2000), discover and understand the fabulous silent underwater world (Popovici et al. 2004), or learn to read (Popovici et al. 2005) or write (Robertson and Oberlander 2002).

A virtual reality system is different from other computer applications in that it gives the user the sensation of being in the virtual world and being able to act on it. Therefore this notion of the user's presence in the VE has two components, which are immersion and interaction. To be more complete, a VE does not only ensure this user presence, but something must also "happen" and not just as the result of a user action. Consequently, the objects of the environment have to evolve using autonomous behaviours. This notion of autonomy is essential in order to associate the multisensory feedback from graphic data processing with the behavioural rendering needed in virtual reality.

In a VE, the learner is confronted with variable situations and a complex world. This variability (brought on by the autonomy of certain entities in certain contexts) is doubly interesting in order to construct new knowledge by abstraction. Either the learning is procedural, where the point is to acquire skills based on know-how, or the learning is declarative, where the skills require an effort of comprehension and the mobilisation of knowledge. More generally, the systematic and random variability of contexts has been presented as an essential condition for abstraction and therefore, for transfer (Mendelsohn 1996). Varied practice, i.e. successions of different (but analogous) situations, produces interferences between situations, which contribute to forgetfulness: only the points two situations have in common are kept in mind. Computer simulations (enabling numerous repetitions) and using virtual reality (allowing a wide range of situations thanks to the agents' autonomy) offer interesting perspectives for transfer.

It has generally been assumed that training in a VE will transfer to subsequent real world performance. However, what is actually transferred? The purpose of the next section is to examine studies about transfer issues in VE and emerging trends in this recently developing field.

5 Transfer: a criterion for evaluating VE effectiveness

The question of transfer can be studied through the use of virtual computer simulations. The VE seems to be an ideal medium for training or learning (Psotka 1995; Yungblut 1998). In this case, transfer can be taken as a way to measure the effectiveness of the VE. However, it is extremely difficult to track. Although part of the research carried out has been devoted to understanding it, transfer has remained an elusive concept. Transfer is not so much an instructional and learning technique as "a way of thinking, perceiving, and processing information" (Haskell 2001). More than a simple extension of learning, this process involves complex cognitive processing (Haskell 2001; Tardif 1999).

Before VEs can be widely used as an educational medium it must be demonstrated that skills practised in them can transfer successfully to the real world. The salient or critical features of the real world probably make it more likely that the skills will be transferred successfully. Where risk is a factor they allow the user to learn by making mistakes without suffering the real consequences of their errors.

For VEs to be of any use, learning must obviously be generalised to similar experiences in physical reality (Bricken 1991). An unsuccessful attempt to demonstrate the generalisation of skills learned in a VE (Kozak et al. 1993) attributed the failure to the lack of genuineness of the VE and an overly simplistic task (moving cans to target locations). This finding has been challenged on methodological grounds and disputed by follow-up investigations. More recent studies have found clear evidence of positive transfer of procedural learning from virtual to real environments (Rose et al. 2000) in the field of training. In that of education, Wilson et al. (1996) described successful attempts to teach children with physical disabilities the location of fire exits and emergency equipment using a virtual model of the real building in which they were tested. Another study showed that for shopping skills practised in a virtual supermarket by students with severe learning difficulties, transfer occurred in a shopping task in a real supermarket (Combry et al. 1996).

A set of studies focused on transfer possibilities in the real world for spatial knowledge acquired in VEs. For instance, subjects "virtually" explored a floor in a virtual building. They then transferred the spatial knowledge acquired in VE and found their bearings more easily in the real building (Witmer et al. 1996). Children learn a maze more effectively in VE than with a map (Waller et al. 1998). This potential of spatial knowledge transfer can be used for prepare children to find their way in a place they have not visited before (Volbracht et al. 1998). The degree of presence may be a condition for facilitating this acquisition. "Presence" is the sensation that users are inside the computer-generated environment, interacting with virtual objects, instead of merely looking at the virtual world on a desktop computer screen (Winn 2002, 2003). Presence depends on the coherence of stimulus in virtual reality or number of senses stimulated. We can link this concept to the information-processing model of Craik and Lockhart (1972). The degree of presence also depends on semantic encoding.

In the learning of spatial skills, positive transfer from virtual to real environments has been reported with almost no exceptions (Regian 1997; Waller et al. 1998; Brooks et al. 1999a, b). In the case of procedural learning, early studies have suggested that transfer from virtual to real environments might occur. The general conclusion that training in a VE is beneficial merits further scrutiny. VE is used greatly in education, but transfer is not systematically tested. In the last section, we present our research perspectives to facilitate transfer of learning in a VE.

6 Transfer in VE: the learner as a singular context

Since the 70s, the development of learning models has seemed to recognise the interest of "context effects" (Richard 1990). The advantages and limitations of behaviourist, cognitivist and constructivism, theoretical perspectives has introduced a new paradigm, called the situated cognition paradigm.

Lave (1988) was against the very idea of transfer, on the basis that knowledge and skills are context-bound. According to this model, knowledge is situated, i.e. it is a product of the activity, context, and culture in which it is developed and used. Activity and situations are integral for cognition and learning. Finally, from the situated cognition perspective, knowledge and skills cannot be transferred because they are so strongly embedded in and tied to the context in which they are acquired (Anderson et al. 1996). However, a closer look at the literature suggests this conclusion is too simple. As Law (1994) showed, the different perspectives on transfer are due to this situated cognition paradigm.

First, learners could acquire knowledge in response to the constraints and affordances (Gibson 1977) of the learning situation. Transfer of knowledge to a new situation involves a transformation of the initial situation and an invariant interaction of the learner in the new context. Transfer can occur when the transformed situation contains similar constraints and affordances to the initial context that are perceived as such by the learner (Bracke 1998; De Corte 1999). In line with this situative view, Lobato (2002) recently proposed a new view of transfer which she calls "actor-oriented transfer". Actor-oriented transfer is defined as the personal construction of relations of similarity across activities, or how "actors" see situations as being similar.

Therefore, this knowledge must be learned in context, in the actual work setting or in a highly realistic or "virtual" surrogate of the actual work environment (McClellan 1991). In agreement with this, we propose to analyze a VE training programme using situated learning as a yardstick. Learning consists in linking shared information from a personal context (knowledge, skills, emotions, etc.) with an external learning context (visual properties of VET) (Kokinov 2003).

According to Kokinov (1995) and his dynamic theory of context, context is the "set of all entities that influence human behaviour on a particular occasion, i.e. the set of elements that produce context effects". "External context refers to the physical and social environment or the setting within which the subject's behaviour is generated. Internal context refers to subject's current mental state within which the subject's behaviour is generated". When studies concern a particular aspect of a subject's activity, such as transfer of learning here, we can consider that the set of elements also constitute an internal context, which may influence, explicate, and describe this transfer of learning. In this case, context refers to the subject's subjective point of view. It can be broken down to a few elements perceived as being important for the subject's activity. Yet in the same environment (VE), different contexts could be perceived by learners or trainees. Considering both contexts should lead to an approach providing better understanding of transfer, not only in describing the transfer process but also in attempting to identify the conditions which facilitate it. Understanding the process of transfer from the virtual to real environment means modelling the interaction between internal and external contexts in both source and target situation.

Environmental conditions should be controlled, modified, or arranged by the instructor to simulate increasingly difficult conditions, for example. The learning environment will be contextually rich and highly realistic. Learning is present, since the instructor decides which array of interlocking problems to present in each simulated environment. Learners or trainees must gain experience with different sets of problems in order to build the necessary skills to achieve the VET's purpose.

Virtual simulation provides the opportunity for multiple practice sessions, including practice where different factors are connected. In this respect, many VEs for training provide feedback on performance, which is electronically monitored and recorded. The training program highlights stories, whether of real disasters or simulated scenarios of crisis situations representing the full range of potential technical and human problems that a trainee might encounter in the real world.

Our research should include two kinds of hypothesis, i.e. a high one and a low one. The low hypothesis includes the context from the environmental point of view. Virtual reality with intelligent tutoring systems should individualise the learning process. Varying the context should enable autonomy, various forms of aid and different levels of pedagogical intervention. The challenge will be to measure the pedagogical effects on transfer.

In contrast, the high hypothesis should be oriented by the idea that context depends on the subject's point of view (situation). The learner's personal characteristics should be fed into the VET and should provide a specific, singular situation, which facilitates learning and transfer.

In our technological society, people must adapt to frequent change and upheavals. Research education must aim to facilitate the adequate use of knowledge in developing autonomy and adapting in daily life (Bracke 1998). The question of knowledge transfer in this context is fundamental. In the coming century, educational and professional fields will have to find responses to this end.

In conclusion, there is an obvious need for further investigations to acquire better and deeper understanding of the processes underlying transfer. We also need effective research-based and practically applicable ways of facilitating transfer in learners within different educational and training VEs.

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