Footprinting e-learners' activity: A first step to help their appropriation of the training system?

Magali Ollagnier-Beldame

Footprinting E-Learners' Activity: A First Step to Help their Appropriation of the Training System?

Magali Ollagnier-Beldame
Post-doctoral researcher
Chambéry Management School, France
Liris laboratory, Lyon1 University, France
m.beldame@esc-chambery.fr
mbeldame@liris.cnrs.fr

Abstract: Information and communication technologies have invaded the field of training, though their performances have, up until now, been judged by companies to be insufficient. Among the origins of this state of affairs, we consider that the lack of knowledge of what happens in a "real use situation" plays an important role. Indeed, understanding what is involved in learners-system interactions is fundamental to improve the system appropriation and its efficient usage. This appropriation is a dual necessity for learners as they must take over the offered possibilities of interactions and acquire the necessary knowledge. As appropriation is made through offered interactions, we will consider computer interactions traces as potential appropriation facilitators. In this conceptual article, we present a bibliographical research concerning the use of computer interactions traces and we propose a classification of 'tracing systems'. We show the links between these works and the process of appropriation in an instrumented training situation. Finally, we expose an experimental study we conduct on the role of traces of interactions in a collaborative mediated task by using a numerical environment.

Keywords: intelligent learning environments, learner-computer interactions traces, knowledge reuse

Introduction

As in innumerable other fields of activity, information and communication technologies have invaded the field of teaching and training. A recent study of Bersin (2006) shows that North American industries' budget for e-learning and instrumented training amounts to 46.6 billion dollars. The amount spent on external technologies, products and services represents around 14.8 billion dollars. The amount concerned with tele-learning (Learning Management Systems - LMS) represents 3 to 7% of the total expenditure on training in an organisation. In the last few years, a large number of big industrial groups have tried to improve and consolidate the usage that is made of LMSs. According to (Bersin, 2006), in the next 12 months, a third of companies plan to increase the number of systems used within their organisations. Virtual class systems have been adopted in numerous sectors. In (Bersin, 2006) we can read that 60% of the companies listed in the study use virtual classes for company training. In another study from the same group, published in January 2006, the global budget of the LMSs was 480 million dollars.

Moreover, the performances of e-learning solutions have up until now, been judged to be insufficient by the companies. In particular, they do not have a real idea of the results of the implementation of such solutions. Among the reasons for this state of affairs, we think that a lack of knowledge of what happens in a "real use situation" plays an important role. In fact, an understanding of what is involved in the interaction between learner(s) and system(s) is fundamental for improving the appropriation of these systems and for their efficient use. The researchers in the technology enhanced learning field, who study instrumented learning situations, discover flaws in the conceptualization of interactions between learner(s) and system(s), particularly as multiple learners are involved with them: the learner himself, the system designer *etc*. In this context, it seems to us that the fact of tracing the learner-environment interactions is a very interesting path to follow, so that they can be later used to help learners appropriate the system. Besides, it appears to be both relevant and urgent that a typology is proposed for computer assisted learning situations which already use computer traces of the interactions between learner(s) and system(s). This is precisely what this conceptual article is concerned with.

We will firstly present the context of the intelligent learning environments, followed by a classification of the systems tracing interactions. We will finally explain how traces can facilitate the learner's appropriation of the environment.

Technology Enhanced Learning

The research field on instrumented learning and digital environments for human learning has mainly dealt with interactions between learners and technical devices, in particular with regard to digital environments. This therefore concerns digital environments designed with the aim of '*aiding human learning; that is to say, increasing the learner's knowledge*' (Tchounikine, 2002, p. 3). This type of environment enables learners to interact with others, to interact with artificial agents, to gain access to all types of teaching elements which are the resources for the learning activity. They aim to facilitate the building up of a sense, in particular through the collective processes where a sense emerges.

We consider that the question of learner's appropriation of this type of environment is central. In fact, intelligent learning environments are complex environments that are rarely 'intuitive' despite the efforts of their designers. The question of their appropriation and their 'recognition' as instruments by learners, fundamentally motivated our work.

The learners spontaneously 'instrument' their activity *via* their digital environment, using the possibilities of 'available interactions' as a basis. Traces of these interactions should therefore 'naturally' reveal this appropriation to 'provide a sense' for learners.

In the case of an activity which instruments interactions, as it is the case in a situation where an intelligent learning environment is used, a part of these interactions becomes tangible and likely to be observed both by the human (learner) and by the environment (system). A certain number of digital environments make it possible to retain computer traces of interactions which are tangible for a human observer, whether he is the one observed (learner, person who produces traces) and /or an observer of the activity in progress, for example an analyst of the situation. The use of these traces for the means of analysis is quite common in the field of intelligent learning environments when the observer is a teacher or a designer of educative activities (learner follow-up, tutoring), whereas it is an exception when the observer is himself the producer. Therefore, although the theoretical challenges, in terms of design of 'user centred' environments are very important, the research field concerning the 're-use' of experience in the form of a visualization of interaction traces is a field of research that has seldom been explored, and in particular, in the context of human learning.

We therefore think that presenting computer traces of interactions to learners, as 'inscribed knowledge' in the system, can facilitate their appropriation of intelligent learning environments.

Below, we present a classification of the digital environments, which traces the interactions between the learner(s) and the digital environment(s).

Classifying the 'Tracing Systems'

For the rest of this conceptual article, we have retained the following definition for 'computer traces of interactions'. They are 's*equences of information registered by and included in the environment relating to uses a person made of it'*. In the domain of human-computer interaction, tracing learner-environment interactions and using these traces as research tools has existed for a long time (Szilas and Kavakli, 2004). These traces are 'histories', used to understand the interaction situation or to help the learner with his task.

We propose to classify situations related to the use of 'history of interactions' according to the way they are used, and in particular, according to whether they are presented to learners or not. We present here the different situations where computer traces are used and classify them according to the possibilities and the type of operations the tracing environment makes it possible to carry out on these traces.

The following table (

Figure 1) summarizes our classification grid:

Computer traces	For learners	For observers : analysts, tutors, teachers
Without visualization	*Personalization* *Indicators*	*Indicators* *Profiles*
With visualization	*Activities facilitators* *Explicit instrumentation*	*Processes analysis* *Abstractions*

Figure 1. ***The proposed grid to classify Tracing Systems***

In this conceptual article, we are more particularly interested in the use of computer traces of interactions when they are sent back with visualization to learners who produced them during their activity, as shown in figure1.

In the next sections, we illustrate the grid, classify systems according to it, and show that the grid can be an operational tool to distinguish numerical environments.

Environments Using Interactional History Without Presenting it to Learners

The first group of environments we can identify is those which do not present histories of interactions to learners. These environments use learners' environment traces of interactions but they do not exploit them in the form of visualizations. These traces called 'log files' are calculated with the aim of predicting, according to an implicit model, the future actions of learners, and thus modifying the interface so that it corresponds to the 'predicted' behaviour. The interactions' information, on which calculations are made, corresponds to the information of the following type: access to resources, screen consultations, clicks made, time spent on operations, choices made, answers given to possible questions *etc*. These processes are automatic and are provided for in the programme. In these environments, learners' actions are compared to a model of anticipated actions.

Such environments are thus concerned with the learners' preferences when personalizing the interface. Some of these environments propose interfaces which 'give and take advice' (Lieberman, 2001) by interacting with learners. These interfaces reflect the calculations made on learners-environment interactions stored in memory, by suggesting possible actions to users. The web browser *Letizia* (Lieberman, *op.cit.*), 'gives advice' and proposes assistance to the learner by trying to undertake actions s/he is undertaking for him. The learner can accept, disregard or reject the proposition. While the learner is 'surfing' in the left-hand window, *Letizia* also 'surfs' and proposes advice in the right-hand window. The graphic editor *Mondrian* (Lieberman, *op.cit.*) asks for advice from learners, using concrete and visual examples to show what they are expecting, associated with actions, so that the *Mondrian* environment can interpret the examples. In their state of the art on the question of environments guiding and supporting collaborative learning, Jermann, Soller and Mühlenbrock (2001) qualify these environments as 'advisors' and 'moderators'. These environments analyse the state of collaboration among learners by using an interaction model and offering advice to improve the actual learning. The environmental coach (human or artificial) has the role of guiding learners in a collaborative and effective learning process. According to these authors, since a satisfying collaborative learning process includes as much learning to collaborate, as collaborating in order to maintain the learning process, the environment has to be able to propose advice of a social or collaborative nature as much as advice on the learning task.

Environments Offering a Visualization of Interactional History to Situation Observers

The second group of environments concerns environments offering a visualization of learner-environment interaction traces to the situation observer who is not the learner of the environment. In the context of uses analysis in interactional situations, it can be interesting for the situation analyst (for example a researcher) to have access to traces of the interactions between learners and environments. For a long time, computer traces have been used by researchers to 'spy on' the way 'subjects' behave in a given situation, or use an environment. These types of studies exist in ergonomics, educational sciences, psychology and

communication. Després (2001) developed an environment for an instrumented learning situation, based on interaction traces, enabling a tutor to detect the state of advancement of the learners' work. Another well-known 'spy' used for man-machine interactions, is that of *PlayBack* (Neal and Simons, 1983). A recording of interaction traces can lead to diverse counting procedures: time spent, frequencies of use, functionalities used or not used, errors, rates of success *etc*. (Dubois *et al.*, 2000) cite other, more specific, measures such as the rate of repetition, the rate of composition and the locality (Greenberg and Witten, 1988). For a classification based on traces, methodologies are applied, based on works from the recognition of forms: neural networks and data mining. These methods analyze sequences appearing in traces or all transitions of sequences. (Dubois *et al.*, *op. cit.*), with the aim of taking a large variety of different types of information into consideration, propose a method to analyze use traces in their context, in order to make an ergonomic validation of web sites. They carried out an automatic processing based on the degrees of similitude and correlation in the reference matrix. (Georgeon, Mille and Bellet, 2006) propose the *Abstract* environment (Analysis of Behaviour and Situation for menTal Representation Assessment and Cognitive acTivity modelling) to trace car drivers' actions and to analyze them. Five sources of data are integrated into traces: video data from different cameras on the vehicle, measures from the vehicle's interior, information from a telemeter, navigation data from a GPS and events triggered by the investigator. In the context of a learning process, the files obtained from a learner can be used to characterize interactions and make a model of the learner by the researcher. According to Renié (2000), interaction traces give information on the operations which can be correlated with other parameters, such as the results obtained in tests, and the characteristics of learners, to obtain 'profiles'. In these environments, an objective can be to discover certain 'motives of actions' for the learners through the means of statistical calculations.

Environments Offering a Visualization of Interactional History to Learners and Proposing Possibilities of Browsing Actions

The third group of environments offers a visualization of interaction traces to learners and enables them to browse in this information. These environments present the interactional history to learners to make their activities easier. The possibilities for learners to interact with this history are limited to the browsing and do not concern the undertaking of new actions nor the entering of information which triggers these actions. Certain environments concern browsing, others are intended to learning situations.

Web Browsing Environments

Reviewing past events is useful in numerous contexts. Greenberg and Witten (1988) were interested very early in the fact that users repeat their actions when using computers. They noticed that users repeated certain operations and took an interest in the possibilities offered by environments to encourage re-using (e.g. teletypewriters, graphic selections, editions, browsing in menus, predictions and programming). A study of web browsing shows, for example, that 58% of the URLs consulted by users had already been consulted by these same users (Tauscher and Greenberg, 1997), and that, consequently, web browsing could gain considerable benefit from tools presenting histories. These authors in fact analyzed six weeks of use of a browser by 23 users with the following objectives: to understand the way in which the users revisit web pages, to see if 'repeated motives' exist for reusing them, to assess the types of existing histories in the current browsers, and to create design indications for the new 'historical environments' associated with browsers. They showed that users frequently revisit the pages they have already visited, but also that they continue to visit new ones, often just

once. Concerning the pages that were visited several times, they showed that the last visited pages were often re-solicited - 30% of browsing actions consisting in using the 'Back' button of the browser. Unfortunately, whereas most of the browsers propose historical functions, they are in general limited and not very satisfying.

There has also been a debate on the representation of the history: in a linear form, in a tree structure, in a network or other forms (Hightower *et al.*, 1998 ; Greenberg and Cockburn, 1999). *Webmap* (Doemel, 1994) is a browser extension which provides a graphical link between web pages. The *PadPrints* environment (Hightower *et al.*, 1998) is a 'companion' of the browser which dynamically constructs a map of the history of visited web pages. The map represents the consulted URLs in a tree structure to be read from left to right. According to these authors, the web pages are revisited, but the users do not use the history proposed by the browser. They prefer the 'Back' button of the browser. The authors explain that this is because of the three main limitations which are the incompleteness, the textual form and the cumbersome aspect of the histories. Greenberg and Cockburn (1999), while studying the field of web browsing and the implication of the histories, considered the role of the 'Back' button of the browser. They showed that the 'Back' and 'Forward' buttons are frequently used in order to revisit pages, more than the histories and the bookmarks. These results were confirmed by Cockburn and Jones (2000) who developed the web browsing aid environment, *WebNet*, using a graphical and dynamic representation of user's browsing actions. With the *Specter* environment, Schneider, Bauer and Kröner (2005), propose an 'artificial memory' to help users by increasing their perception. The idea is a dual one. Firstly, such a memory could provide support by taking the context into account, and considering the previous experiences connected with similar situational contexts. Secondly, this memory could supplement the subject's 'natural' memory and could be used to find the information again. Based on a memory model, inspired by the cognitivist models of human memory, this support proposes cooperation between the user and the environment based on ontologies. It proposes reviewing certain of the users' actions, then carrying them out again and posting them. In this environment, the question of the format of traces is considered, which has to be understandable for the *Specter* environment and the users. The environment of Wexelblat and Maes (1999), *Footprints*, proposes to link information relating to the various uses of the web browser to the objects manipulated by the user who is browsing. It analyzes the http logs of a server in order to make a graph of the browsing done by users. The *Footprints* environment is one of the 'social browsing' support environments. Social browsing is a process which consists of using signals or traces originating from other people, for example by using posting or classifying, to make the task easier. It is a way of 'finding information in the activities of others', through communication and interactions. It can be direct, *i.e.* explicit, for example someone says 'You should go to another cinema', or indirect *i.e.* implicit, for example someone who is in the queue for the cinema. It can be planned *versus* fortuitous (Svensson, 2000) according to the relationship with the other person. The idea is to use the history of interactions from previous uses of environments as part of the learner interface, that is to say, to use the traced information that is useful for the task in hand. The interactional history between users and the learning environment emerges in the interface between these learners, where interactions take place. In fact, digital environments lack historical traces and the representations do not integrate traces of use or interactions into the environment which are visible for learners. However, the richness as well as the form of these traces modify the way learners perceive the objects of interaction, the way they appropriate, consider and reuse them.

Environments Dedicated to Learning

Histories of interactions can be beneficial to learners in numerous fields. They can help learners to improve their skills, through research in digital libraries, word processing tasks, computer-assisted design tools, environments which aid electronic performance and web browsers (Hill and Hollan, 1993 ; Wexelblat and Maes, 1999). According to Plaisant *et alii* (1999), proposing an understandable recording of their actions can help learners to regulate their activities by considering their progression and their experiences. This can also help the collaboration between learners. In fact, an ability to record the activities can be beneficial for learners: a complete session can be recorded, in such a way that peers or tutors can analyze the work carried out. The *SimPLE* (Simulated Process in a Learning Environment) environment replaces learning histories by a learning environment based on simulations (Plaisant *et al.*, 1999). *SimPLE* includes a module called a 'visual historian' which provides learners with the means of interacting with the recorded histories: possibility of posting, replaying, editing parts of the history or the complete history. (Carroll *et al.* 1996 ; Guzdial *et al.*, 1996) suggest that learning histories are useful because they encourage cognitive activities concerning cognitive processes (we are here speaking of 'metacognitive' activities) because of the support that they provide to learners in terms of control of their activity and reflections made on their progress. According to these authors, giving learners access to their past experiences can help them to understand what they have done, to correct/ modify an event, to replay their history, to save their histories so that they can replay them later, to consult them with their peers or tutors or to search for events in these histories.

In the field of digital environments for human learning, tools exist for visualizing learners' click stream, developed to support reflective activities and learners' 'metacognitive' adjustments. These tools are based on the idea that using computer traces of learners' activities is a means which helps in the understanding of the learning process. This reflection with regard to the task, called 'reflective follow up' (Katz and Lesgold, 1992), enables learners to visualize traces of their actions and performance, leading them to an awareness which makes it possible to carry out the 'metacognitive' adjustments. In this approach, the principal difficulties involved are to be able to detect, trace, model and represent actions that are significant for the learner, as Gama (2003) showed. *Sherlock II* (Katz and Lesgold, *op. cit.*) is an example of an environment using this type of reflective incitation. Carroll *et alii* (1996) developed an environment, called the 'Journal for Assessing Learning', which is based on all the information recorded during learning sessions, an that is then proposed to support reflective activities.

Environments Offering a Visualization of Interactional History to Learners and Proposing Possibilities for Actions other than Browsing

The last group of environments we can identify concerns environments presenting a visualization of learners' interactions history and offering them the possibility to act on it. These environments use the history of interactions as a tool for learners, allowing them to enter their data or commands. We will rapidly describe three of these environments, *Histview*, *Collagen* and *Sherlock.*

In the *Histview* environment of Terveen, McMackin, Amento and Hill (2002), the history of interactions cannot only be visualized and browsed, but it can also enable users to inform the environment of what corresponds the most to their preferences among the propositions made to them. The example showed in the article of Terveen *et alii* concerns an environment processing musical play lists. The user is invited to define his preferences according to his personal history or that of others. A histogram of musical style is proposed to him. In this histogram, two sliding bars represent each style and each artist: one bar for what has been played in the past and one bar for the current choice. The user can act on the second bar,

increasing it or reducing it, which means that he requests more or less music of this type. The modification of one bar leads to a modification of the other choice bars, so that the number of pieces of music continues to be numbered. These authors carried out experiments to empirically test two types of interfaces for their environment, by implementing them into computers and mobile telephones. They also tested the role of the 'historicalness' of the situation according to three situations: the participants had to select pieces of music to be played. A third party of participants had access to the history of their use of the environment, *i.e.* the pieces already listened to as well as the sequences that had been played. Another third party had access to the history of the group, *i.e.* the pieces listened to by all the learners. In the last group, the subjects did not have access to any information of a historical nature. The results of this research are as follows; first, having access to the history made it easier for subjects to select the titles they wished to program. Then, this was done more rapidly that in the situation where there was no access to the history. Finally, it was shorter that in the situation where there was access to the group history.

In a certain number of systems from the fourth group, the history of interactions had been used to replay or to elude the command sequences, with possible variations between the former sequence and the new one. For example, the interface of the *Collagen* environment, described in (Rich and Sidner, 1997), enables an element to be selected in the history of interactions called a 'segment'. This makes it possible to create new commands in a menu linked to the achievement of an objective. The fact of presenting an interactional history to the learner that is explicit and can be manipulated, and the fact that this can be structured according to the preferences of the learner, offer the possibility of transforming the format of the problem to be solved, in the application. Three categories of action can be envisaged. The first one is to stop the course of actions being carried out. The second one is to go backwards (retrying, revisiting or undoing), which makes it possible to go back to the previous level in the problem-solving process. And the third one is to replay the action, therefore making it possible to reuse the previous work in a new context.

Regarding the test interface developed for the *Sherlock* environment (Lesgold *et al.*, 1992), which is an environment for training technicians in avionics, Lemaire and Moore (1994) used as a basis the idea that past human-computer dialogues are sources of knowledge. In this tutoring environment, the history of interactions is used to improve the explanations given to the learner. He can select a past explanation, provided by the environment, and ask the environment to compare it with the current explanation. The environment therefore automatically produces a text comparing the two situations to support the learner's task. When the *Sherlock* environment refers to a previous explanation, it scrolls through the dialogue history to the appropriate point and shows the learner the portion of the dialogue in question. When the learner wishes to refer to another part of the dialogue and asks a question about it, it enables him to locate the zone of the dialogue and ask a question from a range of standard questions. In this environment, the history of the human-computer dialogues can therefore be shown to the learner, but also manipulated by him, and its representation on the screen can be modified according to his preferences.

All the works we have just presented here consider the role played by computer traces in learners' activities. Among these researches, the environments developed for learners presenting a visualization of the history of interactions are based on the hypothesis that this presentation will enable learners to distance themselves from their activity and in this way, would create an activity within an activity, of a reflective nature.

From the classification of 'tracing systems' for learning that we have proposed, and following our first definition of 'traces of interactions', we would now like to specify the role of traces in the appropriation process.

In fact, we would like to have a better understanding of the role that computer traces can play in the particular context of the use of intelligent learning environments. On the question of the role of such systems traces, we would like to underline the fact that, in a 'learning context', learners must first appropriate the environment, before being able to carry out their main task, which consists in assimilating the pedagogical content the system offers.

Traces of Interactions as Appropriation Facilitators

In a situation with a digital environment, the difference between the designer logic and the user logic can be the cause of large disparities and lead to difficulties in the usage that users make of the environment. These disparities correspond to the difference between the functions within the artefacts, *i.e.* previously defined functions whose creation is the basis for the design of the artefact, and the constituted functions, *i.e.* functions created during the usage of the artefacts (Folcher and Rabardel, 2004). This distance that ergonomists have noticed between the recommended usage and the real usage of digital environments, causes problems for users when appropriating the environment. With regard to these difficulties, which, in our opinion, constitute obstacles preventing the 'good' use of intelligent learning environments, we consider that activity traces, when presented to learners can further the understanding that they have of the environment. We therefore put forward the hypothesis that computer traces of interactions, presented to learners, can facilitate learners' appropriation of the digital environment by enhancing the understanding they have of the environment and the possibilities it offers.

Few researches have focused on the appropriation process as such, and we note that even the term 'appropriation' is often used in the "common sense of the word". However, we present below the works of certain authors concerning this process of appropriation.

Millerand *et alii* (2001) define the process of appropriation as being connected with the process of learning and human development and envisage the sense of the term in the same way as Vygotsky. In their view, appropriation is '(…) *the manner in which an individual acquires, masters, transforms or translates the codes, the protocols, the knowledge and the know-how necessary for "correctly" coming to terms with the material objects*'. They propose necessary elements for a socio-cognitive approach of usages, in order to understand the way in which the appropriation of technical devices is achieved. When observing appropriation, they reintroduced the experience concerning the materiality of technique by considering technical devices as partners in learners' activity. They proposed an operating definition of appropriation that could, in their opinion, only be compromised in the context of a temporal process implying transformations of the situation on the part of the learners. Thus according to this perspective, '*learners choose or redefine functions of the device to give a sense to its use until it becomes the object of a new definition.*' And the 'changes of usage' observed can thus be understood as 'elements revealing the dynamics of differentiated appropriation that takes place when practical experience is gained'. According to these authors, it is 'during' the learner's experience of the device that appropriation comes into play, i.e. during the implementation of technique. For Dourish (2003), appropriation is the '*process by which people adopt and adapt technologies, adjusting them to their own practices*'. The process, which is of a reflective nature, is thus, in his view, similar to that of 'personalizing', but which relates to the types of adoption of the technology, and a transformation of the practices, so that they are of a higher level. For (Rabardel and Samurçay, 2001), appropriation corresponds to what Wertsch calls 'mastery' (skills when using a tool, acquired during its usage, and in a given context), and results from a progressive process of instrumental creation. Wertsch (1998) defines appropriation as the process in which a subject takes something which belongs to another to make it his own. It is a non-linear process, which

is difficult, and which leads to tensions between the object of the appropriation and the usage made of it in a particular context, tensions which lead to resistances.

We retain the idea that appropriation is an iterative process where sense negotiation, which is involved when a person uses an object, enables the adoption and the adaptation of the object. Appropriation is, in a certain way, the action of giving a sense to a situation which 'does not have one'. Therefore, the process of appropriation is situated, in our view, between the two moments where the sense is stabilized, in the 'intermediate' periods. We also accept the view, expressed in the works presented here, that appropriation is a process which is linked to a reflective point of view of the person on his activity.

We have here made the connection with some works cited in our classification of tracing environments; this concerns tracing environments which present a visualization of interactional history to learners, proposing different possibilities for browsing or acting on it. These environments offer visualization of interactions to learners, based on meta-cognitive hypothesis, and aim at furthering the learners' reflective awareness of their activity. By 'reflective activity' we mean an activity that has been reflected on, *i.e.* self-orientated. We are referring to an activity considering itself as the object. The idea is that the digital environment can serve as a 'mirror with a memory' for learners, presenting traces. These latter can incite learners to distance themselves from their activities which is at the origin of a meta-type awareness. An example of the use of these principles for sharing knowledge can be found in Komlodi (2002) who applied it to the legal domain through a process of annotation and re-memorization.

Some Experimental Results on the use of traces of interactions

We have conducted a study on the use of traces of interactions in a collaborative mediated task (Ollagnier-Beldame, 2006; Heili and Ollagnier-Beldame, 2008), using a numerical environment and conducting to a vygotskian development of users. Another experimental work is also in progress (Heili and Ollagnier-Beldame, Héraud, 2008; Gendron *et al*., 2008; Cram *et al*., 2008). In this study, we observed dyads of users using a digital artefact to carry out the task that we assigned to them (a co-redaction of a procedural text). 'Raw' traces of their activity appeared on the environmental interface during the course of the activity. These traces appeared in fact as 'imprints' of the users' activities inscribed by and in the environment. We observed if users used the traces or not.

The main result is that traces were used and that they could be qualified differently according to two dimensions: First, depending on the user 'at the origin' of the traces and depending on the user who used them. Second, depending on the 'digital area' of the environment where users left the traces and let them be seen. These traces of interactions proved to be objects aiding the negotiation of activity, objects that were in continuous evolution during the development of the activity. This study provided us with elements for understanding the relationship existing between traces of interactions and knowledge jointly constructed between users. These traces were supports during the communication between users, and they were also the means of interacting with the other person and with oneself, *via* reflexive activity.

This study took the point of view of considering traces of interactions as potential aids in the sense-construction, such as in the process appropriation of computer environments, in particular when the activity is collective. It also permits us to consider design paths we could use for the creation of 'tracing systems'. These types of system in which the interactions only appear because of the interface have been explicitly developed to trace the interactions between users and interactions between users and the environment, and to present them on the interface. The conceptual literature and experiments show clearly that the use of 'tracing

systems' has great potential, but also shows the difficulties in offering 'appropriated' means of exploiting this 'mine' of experience (episodes of activity) to be discovered during the activity, reused, shared and capitalised etc. We are mainly thinking of the design of systems that provide users with the immediate history of their interactions in real time according to the 'points of view', which would open the way for us to look back over the user's activity and the associated processes of human development. In our opinion, it is very likely that the fact of making explicit the user's history of his interactions with the system, with the possibility of acting on it, is an element to consider as a principle to be followed within the same human-centred design process for digital artefacts and, in particular for devices concerned with learning processes.

Conclusion

This conceptual article gave us the opportunity to make a bibliographical research concerning the use of computer traces of interactions in activities mediated by a digital environment. We have distinguished the uses of computer traces according to whether they can be visualized as traces or not. We have also considered the 'addressees' of the visualization, and shown different uses of traces: Firstly, traces 'for' learners but without visualization or personalization. Secondly, traces 'for' learners and with reflective actions in their activity. Thirdly, traces for an observer-analyst and with calculations of indicators. And fourthly, traces 'for' an observer-analyst, with reformulations and abstractions for the purpose of analyzing activities. We have then presented the importance of the appropriation process when it was concerned with sense-construction, in particular in a situation of human learning. Finally, we showed that experimental results confirm our hypothesis concerning the role of interactions traces in a collaborative mediated activity.

With regard to the setting up of mediated learning situations, we suggest that the choice of digital devices offering a *de facto* visualisation of the interaction traces could enable learners to take stock of their activity and have a better control of their learning process as a process situated in the time limit and the 'digital spaces' proposed. In fact, we think that in a learning context, situations where there are collective activities have really a great deal to gain from the implementation of digital environments enabling the exploitation of computer traces of interactions. In fact, in these types of situations, the sense-construction is an explicit necessity and we imagine that argumentative negotiation could really benefit from an aid provided by explicit traces of the interactions among learners and between learners and computers environment (Dillenbourg, 1999).

As a conclusion, the strong dynamic of the current research into computer traces of interactions leaves us confident that a 'knowledge-orientated' research programme will be developed in very good conditions. And we think that this type of research will be able to give us information on the processes occurring when a digital environment is used for human learning. We think that this understanding is, in fact, a necessity for improving the performances of the e-learning solutions that have been implemented, particularly in companies.

Bibliographical references

Carroll, S., Beyerlein, S., Ford, M., and Apple, D. (1996). The Learning Assessment Journal as a tool for structured reflection in process education, In *Proceedings of Frontiers in Education'96*, IEEE, pp. 310-313.

Cram, D., Fuchs, B., Prié, Y., Mille, A. (2008) *An approach to User-Centric Context-Aware Assistance based on Interaction Traces*, Fifth International Workshop Modeling and Reasoning in Context (MRC 2008), Delft, The Netherlands, 8-12 June 2008.

Cockburn, A., and Jones, S., (2000). Which way now? Analysing and easing inadequacies in WWW navigation. *International Journal of Human Computer Studies* (45). 1996, pp. 105-129.

Després C. (2001). Modélisation et Conception d'un Environnement de Suivi Pédagogique Synchrone d'Activités d'Apprentissage à Distance, Thèse de Doctorat. Université du Maine, Le Mans.

Dillenbourg P. (1999). What do you mean by collaborative learning? Chapter 1 In P. Dillenbourg (Ed) *Collaborative-learning: Cognitive and Computational Approaches*, pp.1-19. Oxford, Elsevier.

Doemel, P. (1994). WebMap - A Graphical Hypertext Navigation Tool, In *Proceedings of 2nd International Conference on the World Wide Web*, Chicago, IL, 1994, 785-789.

Dourish, P. (2003). The Appropriation of Interactive Technologies: Some Lessons from Placeless Documents. *Computer-Supported Cooperative Work: Special Issue on Evolving Use of Groupware*, 12, pp. 465-490.

Dubois, J.-M., Dao-Duy, J.-M., and Eldika, S. (2000). L'analyse des traces informatiques des usages : un outil pour valider la conception d'un site web. Dans *Actes des rencontres jeunes chercheurs en Interaction Homme-Machine 2000*, pp. 85-89.

Folcher V., and Rabardel P. (2004). Hommes, artefacts, activités : perspective instrumentale. In P. Falzon (Ed.) *Ergonomie*. Paris : PUF.

Gama, C. (2003). Towards a model of Metacognition Instruction in Interactive Learning Environments. Thèse de Doctorat. University of Sussex, England.

Gendron, E, Carron, T. and Marty, J.-C. (2008); *Collaborative Indicators in Learning Games : an immersive factor,* 2nd European Conference on Games Based Learning, Barcelona, Spain 16-17 Octobre 2008.

Georgeon, O., Mille, A., and Bellet, T. (2006). Analyzing behavioral data for refining cognitive models of operator. Dans *Philosophies and Methodologies for Knowledge Discovery,* Krakow, Poland. IEEE Computer Society Press Proceedings. IEEE.

Greenberg, S., and Witten, I.H. (1988). How Users Repeat Their Actions on Computers: Principles for Design of History Mechanisms. In: Soloway, E., Frye, D., Sheppard, S. B. (Eds) *Proceedings of the ACM CHI 88 Human Factors in Computing Systems Conference.* June 15-19, 1988, Washington, DC, USA. pp.171-178.

Greenberg, S., and Cockburn, A. (1999). Getting Back to Back: Alternate Behaviors for a Web Browser's Back Button. In *Proceedings of the 5th Annual Human Factors and the Web Conference*, Held at NIST, Gaithersburg, Maryland, USA, June 3th.

Guzdial, M., Kolodner, J., Hmelo, C., Narayanan, H., Carlso, D., Rappin, N., Hubscher, R., Turns, J., and Newstetter, W. (1996). The collaboratory notebook, *Communications of the ACM* 39, 4, pp. 32-33.

Heili, J. and Ollagnier-Beldame, M. (2008). *Analyse de l'activité et complexité des interactions homme-machine : Pour une revalorisation des études de cas*, Actes 13eme conférence AIM 2008 Paris pre-ICIS Workshop Paris 2008

Heili, J. and Ollagnier-Beldame, M., Héraud, Jean-Mathias (2008). Traces d'utilisation, utilisation de traces : Application à l'adaptation des IHM. *To appear in proceedings of 13ème Conférence AIM 2008 Paris, Pre-ICIS worshop*, décembre 2008.

Hightower, R., Ring, L., Helfman, J., Bederson, B., and Hollan, J. (1998). Graphical multiscale web histories: A study of PadPrints. In *Proceedings of Hypertext '98*, pp. 58-65.

Hill, W.C., and Hollan, J.D. (1993). History-enriched digital objects, In *Proceedings of Third ACM Conference on Computers, Freedom and Privacy*, San Francisco, CA, ACM, pp. 917-920.

Jermann, P.R., Soller, A., and Mühlenbrock, M. (2001). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. In *Proceedings of European Perspectives on Computer-Supported Collaborative Learning*. Bergen, Norway, pp.324-331.

Katz, S., Lesgold, A., Eggan, G., and Gordin, M. (1992). Modelling the student in Sherlock II. *Artificial Intelligence in Education*, 3(4), pp. 495-518.

Lemaire, B., and Moore, J. (1994). An improved interface for tutorial dialogues: browsing a visual dialogue history, In *Proceedings of the Conference on Human Factors in Computing Systems*, pp. 16-22.

Lesgold, A., Lajoie, S., Bunzo, M., and Eggan G. (1992). Sherlock A Coached Practice Environment for an Electronics Troubleshooting Job. In *Computer Assisted Instruction and Intelligent Tutoring Systems: Shared Goals and Complementary Approaches*, Larkin, Jill, Chabay, Ruth (Eds), Lawrence Erlbaum Associates, Hillsdale, New Jersey.

Lieberman, H. (2001). Interfaces that Give and Take Advice, in Carroll, J. (Ed). *Human-Computer Interaction for the New Millenium,* ACM Press/Addison-Wesley, pp. 475-485.

Millerand, F., Giroux, L., and Proulx, S. (2001). La « culture technique » dans l'appropriation cognitive des TIC. Une étude des usages du courrier électronique, Dans *Actes du colloque international ICUST 2001*, Paris (France). pp. 400-410.

Neal, A. S., and Simons, R. M. (1983). Playback: A method for evaluating the usability of software and its documentation. In *Proceedings of CHI '83*, pp. 78-82.

Ollagnier-Beldame, M. (2006). *Traces d'interactions et processus cognitifs en activité conjointe : Le cas d'une co-rédaction médiée par un artefact numérique*. Thèse de Doctorat. Université Lumière Lyon2, France.

Plaisant, C., Rose, A., Rubloff, G., Salter, R., and Shneiderman, B. (1999). The Design of History Mechanism and Their Use in Collaborative Educational Simulations, in *Proceedings of the Computer Support for Collaborative Learning*, pp. 348-359, Palo Alto, CA.

Rabardel P., and Samurçay R. (2001). From Artifact to Instrument-Mediated Learning, In *Proceedings of International symposium on New challenges to research on Learning*, Helsinki, March 21-23.

Renié, D. (2000). Apport d'une trace informatique dans l'analyse du processus d'apprentissage d'une langue seconde ou étrangère. In Duquette, L., and Laurier, M. (dirs) *Apprendre une langue dans un environnement multimédia*. Outremont, Canada : Les Éditions Logiques, pp. 281-301.

Rich, C., and Sidner, C.L. (1997). Segmented Interaction History in a Collaborative Interface Agent. In *Proceedings of International Conference on Intelligent User Interfaces*. Orlando, FL, pp. 23-30.

Schneider, M., Bauer, M., and Kröner, A. (2005). Building a personal memory for situated user support. In Proceedings of the First International Workshop on Exploiting Context Histories in Smart Environments (ECHISE 2005) at Pervasive 2005, Munich.

Svensson M. (2000). *Defining and designing social navigation*, Licentiate Thesis, Department of computer and system sciences, Stockholm University.

Szilas, N., Kavakli, M. (2006). PastMaster@Strorytelling: A Controlled Interface for Interactive Drama, In *Proceedings of IUI 2006: International Conference on Intelligent user Interfaces*, CSIRO ICT Centre, Macquarie University, Sydney, Australia, 29 January to 1 February, pp288-290.

Tauscher, L., and Greenberg, S. (1997). How People Revisit Web Pages: Empirical Findings and Implications for the Design of History Systems. *International Journal of Human Computer Studies, Special issue on World Wide Web Usability*, 47(1). p97-138, Academic Press.

Tchounikine P. (2002). Pour une ingénierie des Environnements Informatiques pour l'Apprentissage Humain, *Revue I3 information – interaction – intelligence* 2(1). www.revue-i3.org.

Terveen, L.G., McMackin, J., Amento, B., and Hill, W. (2002). *Specifying Preferences Based On User History*, in *Proceedings of CHI'2002* (Minneapolis MN, April). ACM Press, pp. 315-322.

Wertsch, J. (1998). *Mind as Action*. Oxford, Oxford University Press.

Wexelblat A., and Maes P. (1999). Footprints: History-rich tools for information foraging. In Proceedings of ACM CHI 99 Conference on Human Factors in Computing Systems, pp. 270-277.

Net References

Bersin and associates (2006). New study looks at US corporate learning market. Institute for Competitive Intelligence. Available
http://www.trainingreference.co.uk/news/gn060329a.htm