The use of digital traces: a promising basis for the design of adapted information systems?

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THE USE OF DIGITAL TRACES: A PROMISING COMPONENT OF ADAPTIVE INFORMATION SYSTEMS?

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ABSTRACT

Designing information systems with adaptation capacities is a challenge of great importance to improve the appropriation of the system by the users. In this paper we view visualized digital traces as a means to support reflexive type coupling between the system and the user. We examine the way users make use of digital traces with the objective of identifying possible use invariants. This is an indispensable stage in the enrichment of a trace system. We present a case study of an instrumented collaborative situation that answers this question. This case study uses theoretical and methodological tools from cognitive ergonomics that enabled us to integrate the subjects' point of view in the activity analysis. This study allows us to formalize four schemas of trace usage. We discuss these results with regard to the appropriation and adaptation of information systems. This leads us to argue that a trace-based approach is promising for the design of adaptive information systems.

KEYWORDS

Digital traces, reflexivity, use schemas, experimental research.

1. INTRODUCTION

In order to match the users' needs and to become completely incorporated in the users' activity, an Information System (IS) must be thought out and developed by taking the users' characteristics into account. The general idea of an IS design that involves the users throughout the design process is now widely acknowledged. There are several design methods that follow this idea. Such methods put the accent on the active role of the users. These methods seek to take into account some of the user's expertise, and to integrate this expertise as knowledge in the system. The degree to which the users participate in the design is sometimes pursued up to what can be called *co-design in use*. In co-design in use, the system is constantly evolving with the usages. The involvement of the users in the design is thought dynamically. The principle of this mode of co-design rests on the idea that the system records the user's actions as *traces*. Then the system exploits the traces to dynamically 'self-modify'. The system self-modifications are in turn possibly confirmed by the new usages. The system processes the traces to personalize the proposed services by 'anticipating' the user's needs. Generally, these modifications remain implicit, i.e., not visible to the users. The system is implicitly enriched by the users' actions as the system self-adapts to the users. When the changes in the system are implicit, however, we argue that the user lacks an important feedback loop.

Our general hypothesis is that providing the users with an explicit representation of their *use experience* of the system will improve the users' appropriation of the system. We explain this improvement by a *feedback loop* effect. We expect that explicit representations of the use experience will leverage the system adaptation and co-design through usage. Confronting the user with his or her digital traces is, we believe, a means to develop the relation between the user and the IS in the empathy mode, allowing the user to confidently be immersed in the system. Explicit representations of past actions provide feedback to the user and generate what we call a *mirror effect*. The user then envisages the system through an adaptive strategy of reflexive imitation, based on a principle of co-evolution of the system and the user. In our experimental investigations, beyond studying the application of traces, we seek more broadly to think out the future adaptive capacities of systems. We formulate the hypothesis that presenting their traces to the users with the possibility for the users to act on these traces will improve the adaptation of the IS, because traces support a process of making sense.

The study we report here was performed within a broader research project on *tracing systems for reflexivity*. This project lasted three years and brought together public research and several private companies. The project sought to improve an existing system owned by one of the companies involved. The system is a collaborative system for document management. The idea of the project is to enrich the system with digital traces presented to users to personalize the human-machine interface and to support users in their activity. Our study took place at a stage of the project situated early in the process of implementing a trace system in the platform. We had an anticipatory role in understanding the uses of the digital traces with the aim of providing information for the specifications of the future trace system. We planned to analyze the users' actions that concerned using *raw traces* displayed on the screen. We define *raw traces* as elements displayed on the screen that reflect the user's activity while users are using the IS. We wanted to know if users had particular actions *on* - or *with* - elements of raw traces on the screen, what kind of actions, and how frequently. This work thus addresses preliminary questions on IS adaptation based on digital traces: what usages are made of raw traces in IS? Can we identify schemas of usage of raw traces?

We begin this article by presenting a synthesis of the literature about tracing systems for reflexivity. Then we define an experimental set-up to test our hypothesis: the existence of invariants in the use of reflexive raw traces. We present the theoretical framework of the *Course of Action Theory* and the *Instrumental Theory*, before exposing our experimental plan. Finally we present our results before discussing them and concluding.

2. TRACING SYSTEMS FOR REFLEXIVITY

In its broadest definition, a trace is an imprint or a series of imprints left by the action of a human being or a machine. A trace has a double function: first, a trace allows the user to "objectivize" the activity because the trace has the property of exteriority from the object it refers to. Second, a trace allows the user to give meaning to the progress of the activity because the trace results from a past activity and produces signs. As a set of meaningful signs, the trace is interpreted and allows the user to identify the objects that produced the trace. We call *digital trace* a recording of elements of interaction between a user and its environment, within the framework of a given activity. In the domain of human-computer interaction, user-environment interactions have been traced for a long time, and digital traces have already been used as research tools (Szilas and Kavakli, 2004). Researchers usually use traces to understand the situation of interaction or to help users with their task.

In tracing systems, we can distinguish *raw traces* and *interpreted traces*. Raw traces are information that appears *de facto* on the screen throughout the realisation of the activity. But this information is not designed to explicitly constitute traces, it "makes traces" for users. For instance, this information consists of comments on a collaborative document. On the other hand, interpreted traces are reconstructions made by the system. Interpreted traces result from the collection of certain elements and from certain computations on indicators; for instance, "interaction histories" as illustrated in Figure 1.

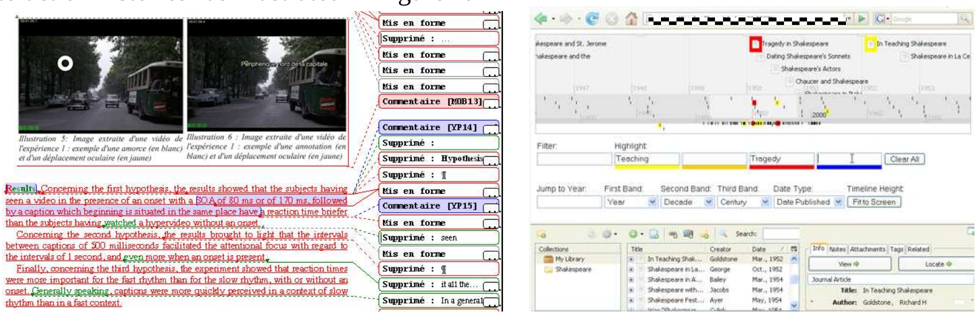

Figure 1: Raw and interpreted traces. On the left, raw traces: comments in a collaborative document. On the right, interpreted traces: interaction history from an online reference tool

In (Ollagnier-Beldame, 2010), we identified different categories of usages of digital traces, in particular, depending on whether traces are presented to the users or not. We report here the different situations in which computer traces are used and we classify these situations according to the possibilities and the type of operations that the tracing environment supports.

Table 1 summarizes our classification grid.

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

Figure 2. A categorization of tracing systems (from Ollagnier-Beldame, 2010)

When presented to the user, digital traces can play the role of activity facilitators. They can also help the user perform an explicit instrumentation of the system because digital traces support reflexive processes. These two aspects of visualized digital traces (grey cell in Table 1) participate actively in the user's appropriation of the system. For this reason, in this article, we mainly focus on the use of digital traces when they are sent back with visualization to the users who produced them.

In the next sections, we present tracing systems that offer visualization to users. In such systems, we can distinguish two groups according to the possibilities of actions on the traces: the systems that support only navigation on the visualized trace (simple browsing), and the systems that support advanced actions on the traces.

2.1 Tracing systems with simple browsing interface

This group refers to environments with visualization of interaction traces that the users can browse. This visualization with browsing facilities is intended to facilitate the user's task. The possibilities for users to interact with this history are, however, limited to browsing the traces and do not permit the undertaking of new actions nor the entering of complementary information. This group includes web browsing environments and learning environments.

2.1.1 Web browsing environments

Reviewing past events is useful in numerous contexts. Greenberg and Witten (1988) were very early on interested 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 goals: to understand the way in which the users revisit web pages, to see if 'repeated motives' existed for reusing such pages, to assess the types of existing histories in the current browsers, and to create design indications for the new 'historical environments' associated with browsers. Tauscher and Greenberg 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 consisted of using the 'Back' button of the browser. Unfortunately, whereas most of the browsers propose historical functions, they are in general limited and not very satisfactory. More recently, (Jatowt at al., 2008) showed that, on the web, there are many benefits to be obtained from integrating documents with their histories. To discuss the possible types of interactions that users could have with document histories, these authors present the results of an online survey conducted with the objective of investigating user needs for temporal support on the Web. Although their results indicated quite low use of Web archives by users, they simultaneously emphasized the users' considerable interest in page histories.

The debate on the representation of the interaction history is of great importance (Grafton and Rosenberg, 2010). Indeed, even if from the most ancient practices, the line has served as the central figure for time representation, interaction histories can take several shapes: such as a tree structure, a network structure, or any other forms (Hightower *et al.*, 1998; Greenberg and Cockburn, 1999; Grafton and Rosenberg, op. cit.). For example, Webmap (Doemel, 1994) offers a browser extension that provides graphical links between web pages.

Obendorf et alii (2007) showed that users frequently access the same pages. In web browsers, revisiting is supported by several features such as back, forward, history, bookmarks, auto URL completion, and the address bar menu. The PadPrints environment (Hightower *et al.*, 1998) is a 'companion' to the browser that 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. According to authors, users prefer the browser's 'Back' button . The authors explain that this is because of three main limitations : 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. Shen et alii (2010) show that the function of revisiting becomes increasingly important. To support users in this kind of task, they suggest a new approach via the use of organic visual (based on the garden metaphor) and contextual cues. With the Specter environment, Schneider *et alii* (2005), propose an 'artificial memory' to help users by increasing their perception. The idea is twofold. First, such a memory could provide support by taking the context into account, and considering the previous experiences connected with similar situational contexts. Second, 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 to review certain of the users' actions, then carry them out again and post 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 that 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. Social browsing 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 waiting in the line 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 user interface, that is to say, to use the traced information that is useful for the task at hand.

This review shows that web browsing environments generally under-exploit historical traces. Traces are not sufficiently integrated in the interface to impact the way users perceive, appropriate, and reuse the objects of interaction.

2.1.2 Learning environments

Histories of interaction can be beneficial to learners in numerous domains. Examples are research in digital libraries, word processing tasks, computer-assisted design, environments which aid electronic performance and web browsing (Hill and Hollan, 1993; Wexelblat and Maes, 1999). According to Plaisant *et alii* (1999), proposing an understandable recording of their actions can help learners regulate their activities by considering their progression and their experiences. This can also help the collaboration between 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' that provides learners with means of interacting with the recorded histories: possibility of posting, replaying, editing parts of the history or the complete history. Carroll *et alii* (1996) and Guzdial *et alii* (1996) suggested that learning histories were useful because they encouraged cognitive activities on cognitive processes ('metacognitive' activities). Guzdial explains this by the support that learning histories provides to learners in terms of control of their own activity. This triggers the learners' reflections on their own cognitive progresses. According to these authors, giving learners access to their past experiences helps them understand what they have done, correct/ modify an event, replay their history, save their histories so that they can replay them later, consult them with their peers or tutors, and search for events in these histories.

Histories of interaction have also been used in e-learning tools. Some of these tools have used visualizations of the learners' stream of mouse clicks. These visualizations were developed to support reflective activities and learners' 'metacognitive' adjustments, with the idea that traces of learners' activities helped both tutors and learners understand the learning process. This reflection on the task, called 'reflective follow up' (Katz and Lesgold, 1992; Hannafin and Hil, 2007), enables learners to visualize traces of their actions and performance, which leads them to an awareness that makes it possible to carry out the 'metacognitive' adjustments (Ambrose *et al.*, 2010). The main difficulties in this approach are managing to detect, to trace, to model, and to represent actions that are meaningful to 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', that is based on all the information recorded during learning sessions that is then proposed to support reflective activities.

2.2 Tracing systems with advanced interface

This group refers to environments with a visualization of the users' interactions history on which the user can act. These environments use the history of interactions as a tool for users, allowing them to enter data or commands. Let us review three of these environments: Histview, Collagen, and Sherlock.

In the Histview environment of Terveen *et alii* (2002), the history of interactions offers not only visualization and browsing but also enables users to state what best corresponds 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 or her. 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 or she 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 in 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 of the 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 of the participants had access to the history of the group, i.e. the pieces listened to by all the users. In the last third, the participants did not have access to any information of a historical nature. The results of this research are as follows; firstly, having access to the history made it easier for participants to select the titles they wished to program. Then, this was done more rapidly than in the situation where there was no access to the history. Finally, it was shorter than in the situation where there was access to the group history.

In a certain number of systems with advanced trace interface, the history of interactions had been used to replay or to elude the command sequences, with possible variations between the recorded sequence and the replayed sequence. 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 a goal. The fact of presenting an interactional history to the user that is explicit and can be manipulated, and the fact that this can be structured according to the user's preferences, offers the possibility of transforming the format of the problem to be solved in the application. Three types of action can be envisaged. The first type of actions stops the course of action being carried out. The second type of actions goes backwards (retrying, revisiting or undoing). This makes it possible to go back to the previous level in the problem-solving process. The third type of actions replays the same action, making it possible to reuse previous work in new contexts.

In the test interface developed for the Sherlock environment (Lesgold *et al.*, 1992)—a tutoring environment for training technicians in avionics—Lemaire and Moore (1994) followed the idea that past human-computer dialogues were sources of knowledge. In Sherlock, the history of interactions is used to improve the explanations given to the user. The user can select a past explanation provided by the environment, and ask the environment to compare it with the current explanation. The environment automatically produces a textual report that compares the two situations to support the user's task. When the Sherlock environment refers to a previous explanation, it scrolls through the dialogue history to the appropriate point and shows the user the portion of the dialogue in question. When the user wishes to refer to another part of the dialogue and asks a question about it, it enables him or her 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 user, but also manipulated by him or her, and its representation on the interface can be modified according to the user's preferences.

The environments presented above were designed to use computer traces to enhance the user's activities. This design rests on the hypothesis that advanced trace interfaces will enable users to distance themselves from their activity, and, in this way, will create an activity within an activity, of a reflective nature.

These environments have been explicitly developed to present users with their history of interactions. Conversely, in our study, we are interested in the uses of the information not planned a priori 'to make trace' for the users. We study the actual uses of the user *with* and *on* digital information that "makes traces" for them, even if these "traces" do not aim at being analyzed, thought or discussed. Our idea is that past or immediate clues have an incidence on the subjects' activity. These traces, constructed automatically by the system but "not interpreted", are "raw" and are *de facto* present in the screen. They are clues from the past activity and from interactions between the user and the system: For instance, traces from communicational interfaces, as collective text editors or chats, where the user constantly sees raw traces of his actions and actions from his collaborator on the screen. We try to identify possible invariants in the use of these raw traces. For that purpose, we use a cognitive ergonomics approach that we describe below.

3. EXPERIMENTAL SITUATION: MATERIAL AND METHOD

Our experiment aims at revealing the reflexive potential of digital traces. We believe this potential can be exploited for the adaptation of IS. We study the uses of information "making traces" for users and we look for possible invariants in these uses. In order to do this, we have chosen a 'reference situation' (Maline, 1994) that we want to analyse to give information about the design of the trace interface in the future platform]. We use systematic methods that we describe below. In particular, we distinguish actions, that can be described in term of schemas, from activities that are complex and depend on the subject history (Vygotski, 1997; Engeström, 1999).

Experimental situation

Our platform is a system for sharing technical information concerning the industrial uses of gas. It is constituted of a set of knowledge bases and contains three 'areas': the technical knowledge base, the experts' directory, and the forum. The goal of the platform is to connect technicians with salesmen in the domains of the industrial use of gas and environment. The platform contains two other back-office areas : the industry base (a sharing tool for technicians) and projects bases.

For the experiment, we videotaped three users using the platform to co-write a technology watch bulletin, this is a natural and usual activity for them. Sargas is the project manager ; he has occupied this post for five years and has been a member of the company research management for eight years. Caiam has been a co-worker in this project for approximately 5 years, and Mebsuta joined the group and the project a few months ago. They draft four technology watch bulletins a year, on the theme of the carbone dioxide storage. This activity is prescribed by the project manager, Sargas, and must be achieved by the members of the team according to a deadline and a certain format (a document about six pages). The team members are encouraged by the project manager to participate. For our observation, Sargas, Caiam and

Mebsuta participated in the writing of this technology watch bulletin, according to the following five-stage scenario:

1. Sargas introduces the writing of the technology watch bulletin
2. Caiam contributes to the bulletin
3. Mebsuta contributes to the bulletin
4. Mebsuta shapes the bulletin and puts it in the documents base
5. Sargas confirms the bulletin and publishes it

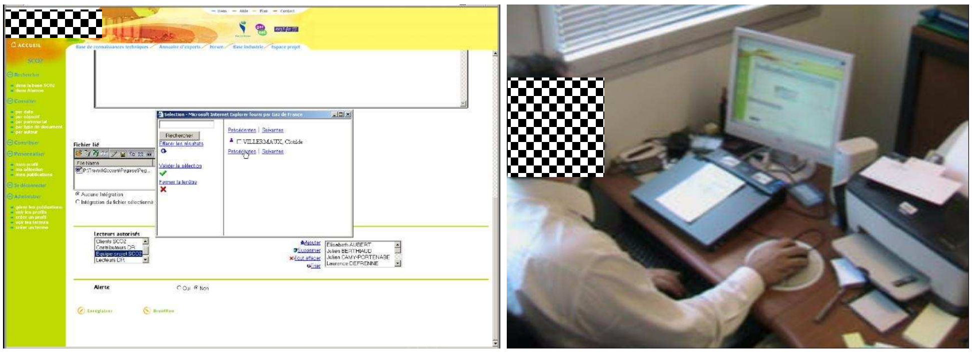

Figure 2. Representative snapshots of the system interface and *external perspective* videotape

Primary and secondary data

The experimental situation is recorded in two synchronous videotapes: a wide plan (external perspective) videotape, and a screen videotape (Figure 2). From these videotapes, we encoded our observations into *chronicles*. These chronicles included three columns: the time, the digital area of the action and the action itself. Table 2 gives an example.

Time	Work Area	Subject’s actions
0:01:08	Taskbar	Sargas crosses the timekeeper on the zone of scrolling of time
0:01:12	Homepage, toolbar of the browser	Sargas clicks the "previous" button of the browser, then display of the list of the publications of the project

Table 2. Extract from the activity chronicle

We use an operational framework for the analysis of the activity: the Course of Action (Theureau, 1992, 2004). Based on the situated action hypothesis, this theoretical and methodological framework aims at reporting the experiential dynamics of knowledge. The method of the Course of Action is based on the main hypothesis that ‘human activity is accompanied all the time with a pre-reflexive consciousness or experience’. This experience includes what we usually call ‘consciousness ‘, but also the implicit dimension of activity. In the activity of a user, it recovers all that can be shown, told, and commented to an observer. This method thus allows for considering the dynamic and situated constituents of the human activity, with the hypothesis that this activity can be *a posteriori* made explicit by the human subject. The idea is that when a user is invited to make his activity explicit *a posteriori*, he cuts it into significant units from his point of view. So, our goal is to reconstruct the course of experience to integrate the context into the analysis of the activity (Theureau, *op. cit.*). For that purpose, we organize a self-confrontation of the user with his videotape (Clot *et al.*, on 2000; Mollo and Falzon, 2004). We ask users to clarify their activity *a posteriori*. Our goal is to discover the significant blocks of experience (SBE) from the users' point of view. We led the self-confrontation sessions with the method called "Explicitation Interviewing" (Vermersch, 1994; Petitmengin and Bitbol, 2009). The self-confrontation sessions are videotaped and subsequently transcribed. This allows us to establish syntheses from the chronicles of the activity, by merging our description of visible actions (from the videotapes) with a description from the users' point of view. The fusion of these two descriptions constitutes a "reduced narrative" (Theureau, *op. cit.*), namely a narrative of the activity progress (Bationo-Tillon, *op. cit.*). The reduced narrative thus appears under the form presented in Table 3.

Object	Script of the interview during the auto-confrontation	Time	Duration	SBE	Work Area	Subject's actions
Selection and copying of text	Mmh > thus by keywords I identified the interesting passage on tt and Lacq, I return to the file, I paste my copy (…) finally I systematically do special pasting without shaping	0:11:40	0:00:06	131	Text editor	Caiam scrolls the content of the document

Table 3. Extract from the reduced narrative

The total duration of the videos to construct the activity chronicle is 01:00:38. Each recording was made according to two perspectives (screen and external perspectives) and the montage thus gave a synchronized tape of 01:00:38. The total duration of the self-confrontation videotapes of the three interviewed subjects is 02:21:02 . During the self-confrontation, the subjects cut their activity into 523 significant blocks of experience. This division led to a reduced narrative that had 523 units of analysis. All the transformations on the data give the following primary and secondary volumes of data:

Material		Sargas	Caiam	Mebsuta
First step	Activity videotape: screen perspective	00:13:54	00:06:24	00:41:41
	Activity videotape: external perspective	00:13:54	00:06:24	00:41:41
	Synchronized editing	01:00:38		
Second step	Self-confrontation Video and audio: external perspective	00:34:15	00:21:34	01:25:13
Third step	Number of SBEs in the reduced narrative	First stage: 100 Fifth stage : 52	68	Third stage: 150 Fourth stage:

				153
		Total: 523 SBEs		

Figure 4. Primary and secondary data volumes

In the above part we described how, from the subjects' words during the self-confrontation we constituted a reduced narrative of their activity, cut into SBEs. This reduced narrative was the raw material for the identification of recurrences in the co-writers "dones". These "dones" are *use schemas*. We describe below the theoretical and methodological procedure that allowed us to extract the use schemas from the reduced narrative. Our analysis is based on the *Instrumental Theory* that aims to bring significant activity invariants to the foreground. Instrumental Theory is based on the concept of action schema and use schema. An action schema is what is general in the action, what can be repeated in similar circumstances (Piaget, 1970). Rabardel (*op.cit.*) defines the notion of *usage schemas* as schemas bound to the usage of an artefact, which concerns two dimensions of the activity: the activities relative to the 'second' tasks (management of the characteristics and the particular properties of the artefact), and the 'first', main activities, directed to the object of the activity, and for which the artefact is a means of realization. This leads the author to distinguish two levels of schemas among the usage schemas:

- The *use schemas* that relate to the 'second' tasks. What characterizes use schemas is their orientation towards the second tasks corresponding to the actions and the specific activities directly bound to the artefact
- The *instrumented action schemas* that consist of *totalities*. The meaning of a totality is given by the global act aiming at operating transformations on the object of the activity. Instrumented action schemas incorporate, as constituents, the use schemas. What characterizes instrumented action schemas is that they are relative to the 'first' tasks.

In our experiment, the main activity is the co-writing. It mobilizes instrumented action schemas and incorporates some use schemas at the same time. Use schemas are the actions that the subjects implement to achieve their main activity. The co-writing we observe is supported by a platform that presents raw traces as the activity spreads in time. The use of these raw traces constitutes a means to realize the co-writing activity. Our goal is to identify traces use schemas allowing the development of the activity. Use schemas emerge from our analysis by induction: they are models of recurring actions we extract from the reduced narrative. We present the use schemas in the following section.

4. RESULTS

In this section we present the activity artefacts we identified from the observation and the reduced narrative. Then we present the results of our analyses concerning the use schemas of mobilization of raw traces revealed by our structuro-functional analysis.

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4.3 Artefacts of the situation

The subjects used eight artefacts during their co-writing activity: the project base, the technical knowledge base, the text edition software, the text files reading software, the email software, the explorer, the Internet browser, and paper resources.

4.4 Use schemas of mobilization of raw traces

We report here regular sets of operations involving raw traces during the activity. We observed 37 use schemas. We show their distribution by schema type and by activity stage in figure 4. These sets of operations are use schemas in the sense of Rabardel (1995) in the fact that they do not concern the 'first' action of the subjects (the co-writing) but 'second' actions (uses of traces) that allow the realization of the 'first' action. Sections 4.4.1 to 4.4.4 present the four schemas that we identified in our analyses and their occurrences across activity stages. In Section 4.4.1 we give an example from the reduced narrative. We use the semantics detailed in Table 5 to graphically represent use schemas.

Boxes	Rectangular boxes: action of a subject
	Boxes with truncated corners: action of the system
Background	White background: recover from the schema strictly speaking
	Grey background: recover from the action preceding the schema, but necessary for the existence of the schema
Edge	Solid lines: actions always present in the schema
	Dotted lines: optional actions
Link	Solid lines: connect two actions of the same subject
	Bold dotted lines: connect two actions not inevitably of the same subject
	Fine dotted lines: connect two actions of two different users
	Wide grey lines: connect two actions between subject and system

Table 5. Graphic representation for use schemas

We present the schemas below and for the first one we give an example from the reduced narrative.

4.4.1 Use schema called 're-use of raw traces'

We observed 8 sets of actions on raw traces that we qualified as 're-use'. In these actions, users re-used productions written for the technology watch bulletin, produced by themselves or by their partners. This schema begins with an action of the user (or of another user) which causes the appearance of a raw trace on the screen. The user selects a piece of this trace. Then, either he copies it, pastes it and erases it, or he cuts the piece of trace and pastes it. These operations were observed from available actions in the menus or from keyboard hot keys (as it is the case in the illustrative example). This schema is represented diagrammatically in Figure 6.

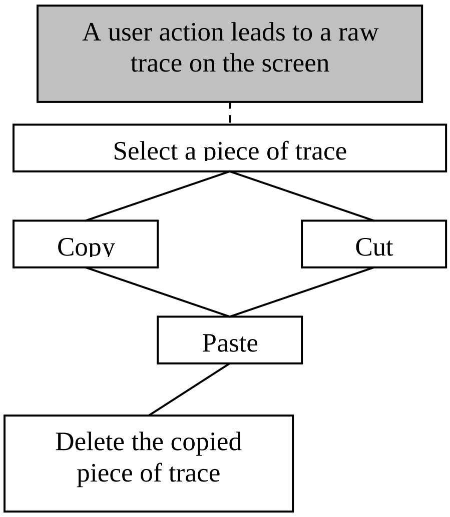

Figure 6. Re-use schema

Object	Auto-confrontation	Time	Duration	SBE	Work Area	Subject's actions
Copying and pasting text between two documents	Mmh thus there you return to the document > thus there I make copy to paste, I copy the text onto the square of the previous text which > everything in the keyboard > yes >	0:29:21	0:00:05	211	Taskbar	Mebsuta clicks the label of the window of the software. Reopening of the document
		0:29:26	0:00:02	212	Text editor, Body of the document	**Mebsuta selects some text (*ctrl a*)** of the contribution of Sargas and **makes a "copy" with the keyboard (*ctrl c*)**
		0:29:28	0:00:05	213	Taskbar	Mebsuta clicks the label of the window of the software. Reopening of the document
		0:29:33	0:00:06	214	Text editor, Body of the document	Mebsuta selects some text (the paragraphs of the first part, below titre1)
		0:29:39	0:00:05	215	Text editor, Body of the document	**Mebsuta makes one "paste" action (*ctrl v*) with the keyboard.** Appearance of the copied text in the document. This text appears with a shaping different from that of the document

Figure 7. Reduced narrative illustration of an occurrence of the re-use schema. We see the selection, the copying then the pasting of the text by Mebsuta.

4.4.2 Use schema called ‘modelling of raw traces’

We found 9 sets of actions on raw traces ending in a voluntary modification of their appearance on the screen. We called this schema the ‘modelling’ of traces. It corresponds to the fact of giving a new shape, a new aspect to raw traces by transformation operations. This schema can be described as follows. An action of the user (or of another user) brings about the appearance of a raw trace on the screen. Then the user selects a piece of the trace. He changes the shape of the trace: he "models" it. This modelling action can be done in various ways. We observed : either the user modifies the shape of the trace directly and freely (for example transforming text in bold text on his own initiative). In this case we observed occurrences of this schema in which the user makes a copy - paste of the piece of trace before shaping it. Or he shapes the trace so that it complies to a desired shape (for example he changes its style in the text editor). This schema can be represented diagrammatically in this way:

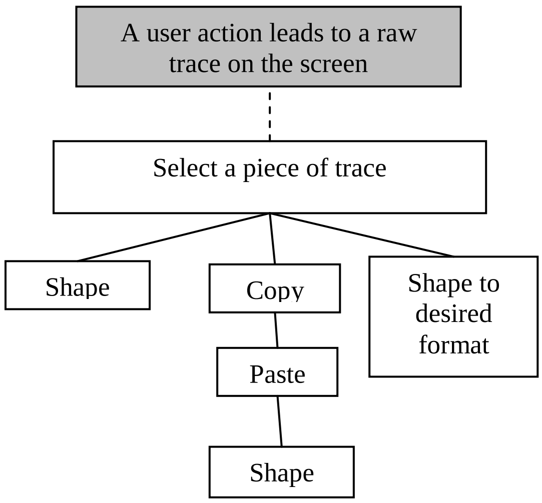

Figure 8. Modelling schema

4.4.3 Use schema called ‘sharing of raw traces’

We identified 4 sets of actions on raw traces in which raw traces are sent to other users for sharing. We called these actions ‘action sharing‘. The sharing can be done in various situations. First, it can be done within the framework of an explicit prescription of sharing, for example at the demand of a manager to send one’s production to others. In the case of a prescription, the sharing can be done from a "fortuitous" trace (if an action of the user – or of another user - causes the appearance of a raw trace on the screen). It can also be done from a trace produced on purpose. Second, the sharing can be freely done, except for prescription. We observed that in that case, it is done either explicitly (for example by sending the trace) after a modelling of the trace, or in an implicit way by modifying a property of the trace—a modification that will be seen by others. This schema is represented diagrammatically in Figure 9:

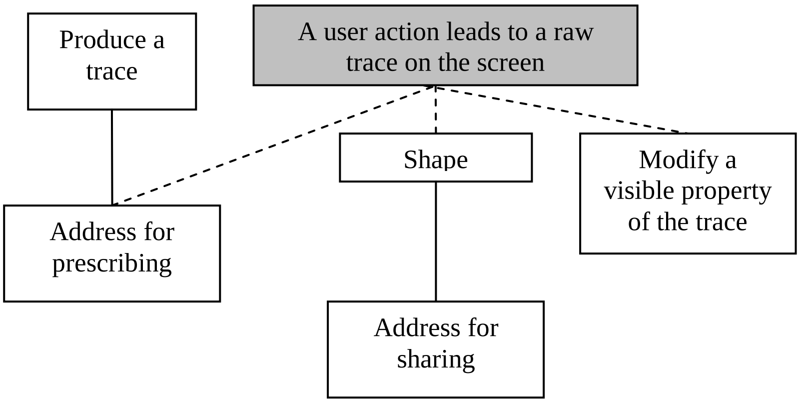

Figure 9. Sharing schema

4.4.4 Use schema called 'consultation of raw trace'

We observed 16 sets of actions on raw traces in which they are examined by the users. We called this schema 'consultation'. It consists of the consultation of an announcement built by the system as a result of a production of raw trace by a subject. In this schema, an action of the user causes the appearance of a raw trace on the screen. Further to this appearance, the system represents a new property of the trace. For example, further to the posting of a message in the forum by the user, the system adds an icon "new message" near the posted message. The user then consults the trace. This schema can be represented diagrammatically in this way:

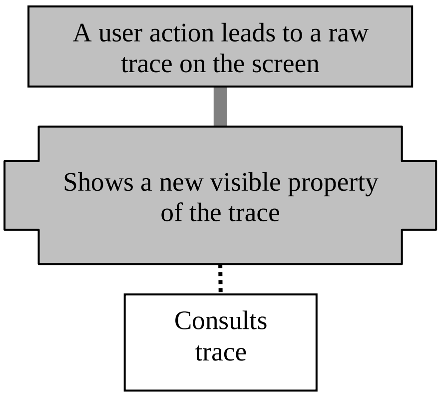

Figure 10. Consultation schema

4.5 Presence of schemas according to the activity stages

Figure 10 shows the distribution of use schemas according to their type and according to the stages of the activity.

Use	Stage 1:	Stage 2:	Stage 3:	Stage 4:	Stage 5:	Total

schemas types	Sargas introduces the writing of the technology watch bulletin	Caiam contributes to the bulletin	Mebsuta contributes to the bulletin	Mebsuta shapes the bulletin and puts it in the documents base	Sargas confirms the bulletin and publishes it	
Trace re-use	-	-	5	3	-	8
Trace modelling	-	3	6	-	-	9
Trace Sharing	2	1	1	-	-	4
Trace consultation	4	3	2	6	1	16
Total	6	7	14	9	1	37

Figure 10. Distribution of use schemas according to their type and the activity stages.

The methodology we used to obtain use schemas and their occurrences is qualitative and does not try to statistically report the presence of the phenomena. However, we can see that the occurrences of the consultation use schema represent almost half the total occurrences (16/37): traces are consulted in the course of activity to continue the activity. We also see that occurrences of the modelling use schema (the user changes the shape of traces) are very present (9/37) as well as occurrences of the re-use use schema (the user reuses traces) that we observed in 8 cases on 37.

Our study concerns the use of a collaborative platform for a co-writing activity. Although the subjects used eight artefacts in their environment, we are specifically interested in three artefacts that belong to the platform: The project base, the text edition software, and the technical knowledge base. The four schemas divide up differently in these three artefacts. The re-use schema is present in the three artefacts, and especially in the project base. This area is not, nevertheless, a dedicated area for the manipulation of objects but rather an area planned for the consultation of information. The re-use, which shows itself by a manipulation of what is present on the screen (for example copy / paste actions) thus goes through the common actions of the user and not through the actions explicitly proposed by the platform. The modelling schema is exclusively present in the text editor, this is completely coherent with the fact that it concerns a manipulation area. We see that the modelling schema is often followed by actions of sharing in the text editor, but the sharing schema is also present in actions made in the project base, while we do not find it in the technical knowledge base. We suppose that this is because the project base is more concerned with the communicational dimension of the collaborative activity. Finally, we find the consultation schema in both bases. Bases are knowledge inscription areas in which subjects come to look for information relative to past events.

The results presented above are discussed in the next section. We formulate some remarks about the use schemas by comparing these results with results of previous studies, before showing why it is interesting to consider the raw traces as transitional artefacts.

5. DISCUSSION

We demonstrated the existence of four use schemas of mobilization of raw traces: re-use, modelling, sharing and consultation. This division is an abstraction of moments of human activity that hints at the complexity of this activity in several layers. Our main goal here is to discuss these results according to the properties of traces and with regard to the situation studied. Then, we broaden the discussion beyond this work by questioning the subjective dimension of our experiment, which brings us to consider the raw traces as transitional artefacts allowing for adjustment of the adaptation of the system.

We think it is relevant to examine the properties of the traces for which we identified use schemas. In (Ollagnier-Beldame, 2006), we identified three properties of traces: *belonging*, *persisting*, and *addressing*. The present study essentially highlights the property *belonging* because of the collaborative nature of the task. The property *belonging* is important because the nature of the trace depends on whether the trace is used by the same user who generated it or by a different user. We call 'own traces' the traces that were generated by the same user and 'alter traces' the traces generated by a partner. In the case of our experiment, we observed that, even though the users were used to collaborating in text writing activities, collaboration was only gradually installed. Hence, the sharing schema (that, by definition, presents a collaborative dimension) only appeared in the middle of the activity whereas non-collaborative schemas appeared earlier, in any case when non-collaborative schemas were mobilized in individual context. This effect of the belonging property taught us that it is important to consider the properties of traces if we want to integrate traces as supports for the adaptation of IS. In future analysis of our data, we will characterize the traces more precisely according to their properties to produce more information in that direction.

The schemas we identified are use schemas; they do not directly belong to the main activity but they make it possible. Yet, it seems relevant to re-place these schemas in the general context of the co-writing activity. Many researchers (Kraut *et al.*, 1990; Dillon, 1993; Mitchell *et al.*, 1995; Cerratto, 1999; Cerratto and Rodriguez, 2002; Cerratto Pargman, 2005) have studied the way in which people write collaboratively. Most of these studies agree that collaborative writing requires moments of writing and moments of communication, periods of synchronous activity where the group works together and periods of individual activity, where the members of the group work in an asynchronous way. Mitchell *et alii* (*op.cit*) showed that the co-writing activity mobilizes two types of individual awareness: self-awareness and collaborator awareness. These two facets of awareness have, we believe, an influence on the schemas that we observe: the fact of reusing the traces of one's past experience and of consulting one's own traces seems linked to self-awareness. In the same way, actions that aim at sharing traces appear in connection with the progressive implementation of collaborator awareness and its preservation during the time of the activity. A limit of our work is to have considered a single collaborative working situation. We made this choice to privilege 'micro' level analysis, using the *Course of Action* and the *Instrumental Theory*. To enrich this study, it would be interesting to see if the same schemas occur in other configurations of collaborative design.

Furthermore, it seems important to replace the existence of these schemas in connection with other pre-existent users' schemas that probably interfered with the expected procedures. We think in particular of the uses that are made in other contexts with reminders, bookmarks, notes, *etc*. These various objects represent the crystallization of procedures of re-use of experience and its capitalization to allow a future activity.

These last two points bring us to believe that the digital traces can be thought of as transitional artefacts for the subject's activity. It is about intermediaries passing in transit between one another or between themselves at a given moment and themselves at another given moment. Bationo-Tillon (2006) defines the concept of transitional artefact from authors' works which are interested in mediation in their reflection, such as Rabardel (1995), Tisseron (1999) and Winnicott (1971). She reminds us that for Winnicott, the transitional area for the adult is a relay allowing the feeling that the experience did not brutally end. It is an intermediate area of experience that allows continuity in time and keeping the link with its experience while being able to objectivise it, consider it as outside oneself. Tisseron (*op. cit.*) underlines that objects are permanent instruments of mediation for the psychic assimilation of our experiences of the world. For Rabardel (*op. cit.*) objects are potential instruments, mediators of three types of connections to the world: towards the object of the activity, towards the others and towards oneself. These artefacts thus go in transit from a situation to another while maintaining a certain perpetuity, a durability of the experience of the subject, preserving certain information. Bationo-Tillon (*op. cit.*) differentiate various types of transitional artefacts: The transitional artefacts 'mirrors', which are reused as such, the 'translated' transitional artefacts, which are retranscribed from one media to another, the 'cumulative' transitional artefacts, extracted from the situation then combined, the 'pragmatic' transitional artefacts, which are collected and then provoke actions, the 'elliptic' transitional artefacts, completed by new elements and finally the transitional artefact 'ghosts', who will not be reused. From our point of view these various types of artefacts are not excluded, except artefact 'mirrors' and the 'translated' artefacts, as well as artefacts 'ghosts who oppose all the others but which we shall not consider because we are interested here in the uses of traces. On the contrary the various traces in the use schemas of mobilization of raw traces can belong to several categories of transitional artefacts. Traces used in the re-use schema can be considered as artefact mirrors, often cumulative. In this schema, an existing trace is reused. The traces of the modelling schema possess the properties of the translated artefacts, which is logical because the modelling corresponds to a kind of translation. The traces of the sharing schema are translated and generally elliptic transitional artefacts. So the translation seems necessary for sharing, to participate in the construction of a common representation. The traces of the consultation schema are transitional artefact mirrors because it is a question of consulting traces produced by the system 'as such'.

As a conclusion, our experiment reveals the interest of the user in his own activity. He notices digital traces, produced by his co-worker or by himself, which then make sense for him as transitional objects. The way these traces are reused can be then described in terms of schemas. However, these digital traces are not a "given raw product" of the digital support. Either they are constructed by computer specialists, for example meeting the requirements of computer maintenance (*system log*); or they correspond to a different feature, and thus correspond to a diversion of an initial usage of the system. So, with the objective of designing adapted IS, it seems interesting to think about the role of traces and their integration in systems as support for their appropriation. In particular, to strengthen the reflexivity of the user, it can be interesting to propose digital traces which are especially designed for their re-use. Then it seems interesting to consider the properties of the transitional artefacts that Bationo-Tillon (*op. cit.*) summarizes in this way: the user attributes to them a particular status of reminder, witness, and 'keeper' of traces of a lived experience. The user 'transits' these artefacts from one situation (a place, an area, a time and a given context) to another one. He uses these artefacts in various intermittent activities in time, thus in activities of a different nature rooted in different situations. Finally, the user can transit these artefacts from one support to another one, from one shape to another ; they are 'convertible' artefacts. The digital traces can be used for the development of the adaptation capabilities of the IS.

6. CONCLUSION

In this article, we presented an original approach to considering future adaptation capabilities of IS based on activity traces: the study of raw traces and their associated uses schemas. Based on a study of a joint design activity with an anthropo-centred methodology , we have shown that interactive traces constituted resources for the activity, and that traces properties were fundamental to understanding how the users mobilized the traces. We also revealed some invariants in the uses of traces. We showed that, to take part in the specification of new trace based systems, it is relevant to study the actual uses of the subjects *with* and *on* digital information which "make traces" for them, even if these "traces" are not intended to be analyzed, thought about or discussed. Past or immediate clues have an incidence on our present activity, in a similar way as the visibility of their heartbeats has an impact on cyclists' behaviour and helps them regulate it. For instance, in the co-conception situations, being able to situate the contributions and the documents of each collaborator in a timeline improves collaborative work. If, in addition, traces are "mobilizable" (filterable, combinable, dividable, *etc.*), then traces enrich and support the joint activity even more. In this experiment, the principle of 'making explicit' the use experience is central. This approach intervened at two levels of our activity analysis. First, for the user himself, we put forward the strong hypothesis that making the use experience explicit in the form of traces displayed on the screen would improve the IS's usability. We advanced the idea that the trace display would help the user later on in his activity by facilitating reflexive awareness. Following this idea, we looked for the existence of possible invariants in the use of traces. Second, the construction of our data was also based on the subjects' explicit experience. From this point of view, the explicit experience played the role of a tool to access the past, a support for exchange between the user and us to reconstruct together the user's operating modes in the situation. In that case, the explicit experience constituted a means to reach processes that are often poorly formalized for users. Our whole approach thus addresses a stake situated at the centre of the subjective experience of use of an IS and its explication. The originality of our work is to focus on what the users did with traces by questioning their point of view. This approach allowed us to discover four use schemas of mobilization of traces in a co-writing activity. Because the situation of co-writing that we studied is representative of many co-design situations, we argue that what we discovered can be generalized to other joint situations of co-design.

This study thus showed the relevance of considering traces as supports for the activity and for the appropriation of IS. We saw that raw traces constitute resources for the activity so we can consider them as transitional artefacts. We showed that it is relevant to think of how the *re-use schema* and the *consultation schema* were engaged in actions where traces have mirror properties, while the *modelling schema* and the *sharing schema* are more present in actions with translation properties. The raw traces constitute transitional artefacts that support the incorporation of the system by users. This incorporation is one of the goals aimed for by the design of systems with adaptation capabilities. Consequently, we think that the addition of explicit traces offering possibilities of actions such as those revealed in this study is a means of extending the relation between the user and the IS to the mode of a shared understanding.

As a conclusion, we think that in a collaborative context, situations have much to gain from the implementation of adapted digital environments exploiting digital traces. In fact, in the adaptation process, making sense is an explicit necessity and we imagine that this could really benefit from assistance provided by explicit traces of the interactions between users and the IS. Finally, we think that this type of research will be able to provide information about the adaptation processes occurring when a digital environment is used for collaborative activities. We think that this understanding is, in fact, a necessity for improving the performances and the suitability of future implemented adaptation solutions.

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