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STUDYING ACTIVITY IN MANUAL WORK: A FRAMEWORK FOR ANALYSIS AND TRAINING

ÉTUDIER L'ACTIVITÉ DE TRAVAIL MANUEL : UN CADRE POUR L'ANALYSE ET LA FORMATION

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SUMMARY

This paper presents the methodological framework that we developed for collecting, studying and passing on tacit and explicit know-how embodied in the professional gestures of expert workers. This framework is based on the adaptation and combination of a range of psychological theories and techniques: the Activity Theory, the 'Perceived Quality' approach, Subjective Evidence-Based Ethnography, and verbal protocols. The application of the method, which focuses primarily on the perspective of the expert, has enabled us to build a cognitive model of the professional gesture to be transmitted, by highlighting its key points. It has led to the development of multimedia training products called MAPs (Multimedia Platform for Apprenticeship) designed to "represent" and convey knowledge involved in the real-time performance of the expert's gesture. The methodology was developed and applied to manual operators, in actual work and training settings in the largest French power company. The practical aim of the study was to address an organisational issue of knowledge management, for professional training purposes, in order to bridge the gap in learning through mentoring between retiring experts and novices. The method has recently been implemented throughout the company in which the research was carried out and could be applied to many other situations and contexts.

Keywords: *Professional Gesture, Video, Subjective Evidence-Based Ethnography, Verbalisation, Activity Theory, Training.*

RÉSUMÉ

Cet article présente une méthode d'étude des savoir-faire incorporés dans les activités de travail manuel, à des fins de transmission pédagogique en situation

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de formation professionnelle. Cette méthode s'adresse donc à une catégorie spécifique d'activité humaine, celle des gestes professionnels. Son développement est le fruit d'une recherche empirique menée au sein d'un grand groupe énergétique français, pour sa branche formation, afin de répondre au double besoin généré par le contexte organisationnel de renouvellement intergénérationnel ; à savoir, capitaliser les connaissances rares et critiques des experts, et être en capacité de les transmettre aux nouveaux arrivants par le biais de solutions de formation numériques innovantes. Le cadre d'analyse se veut avant tout centré sur la perspective de l'expert. Il propose une chaîne opérationnelle assurant le recueil, l'analyse, la formalisation et la transmission effective du savoir-faire tacite et/ou explicite sous-jacent à la réalisation d'un geste professionnel. S'appuyant sur les récents développements de l'ethnographie numérique subjective, le protocole de recueil imbrique des observations vidéo situées de l'activité, en première et troisième personne, avec plusieurs protocoles de verbalisations, dont un simultané à la réalisation du geste et orienté-but. La mise en lien des données « objectives » (observations vidéo) et « subjectives » (ce que l'expert pense et dit) est assurée sur la base : des cadres d'analyse proposés par les théories de l'activité, afin de structurer l'activité ; et d'une approche dite de « qualité perçue ». Cette dernière vise à dégager les dimensions naturelles issues de la perception des affordances du contexte par les participants dont on étudie l'activité. L'application de cette méthode globale permet à l'analyste de construire un modèle cognitif du geste à transmettre. Ce dernier, assorti du matériel vidéo et verbal recueilli, sert de structure de base à la réalisation d'un support didactique véhiculant l'expérience réelle de l'expert.

Mots-clés : *geste professionnel, vidéo, ethnographie subjective, verbalisation, théorie de l'activité, formation.*

I. INTRODUCTION

In the production industry, manual workers develop know-how that is embodied in so-called "professional gestures", segments of work activity calling for expert skills and guided by motives and goals. This notion of the professional gesture refers, therefore, to the idea of expertise acquired and internalised over time. The performance of expert operators is based upon attentional, cognitive and physical processes. It is convenient to distinguish such segments in order to establish protocols for collecting data about this class of activity, as well as analyzing it, which requires skills "embodied in action, difficult to verbalise, and closely related to the context" (Leplat, 1995, p.101). Indeed, our primary goal is to access and externalise both tacit (Nonaka & Takeuchi, 1995; Polanyi, 1967) and explicit know-how, built up and shaped over many years by experts within the framework of their professional practices, with the aim of structuring this expertise into a suitable educational format for transmission purposes.

This paper introduces the theoretical and methodological frameworks which we have developed for collecting data about professional gestures, as well as, analysing, and transmitting them for purposes of professionalisation and training of novices, and as an answer to a real organisational issue of intense intergenerational renewal in the production industry. The task

was two-fold: to provide a solution to an organisational and societal problem of knowledge management, and to answer the needs of professional trainers for efficient, up-to-date training devices and tools, based on new media, such as video. The design of this method is the result of an extensive three-year empirical research project, which enabled us to collect a sample of fifteen cases of professional gestures performed by highly skilled power plant operators, either in a real work situation (power plants), or in a re-created setting (training centre). This research was carried out in the French energy industry, according to the principles of the constructivist approach in ergonomics (Falzon, 2005) and the experimental reality paradigm (Lahlou, Nosulenko, & Samoylenko, 2012).

Section 2 describes the methodological issue of knowledge transmission. Section 3 presents the theoretical and methodological background that we have used and adapted to our specific research needs. Section 4 presents an overview of the method we designed, and is illustrated by an example of practical application. As this method is the fruit of collaboration between French and Russian scientists, we have attempted to give an international dimension to this article, by addressing the issue, from at least a double perspective, according to Russian and European references.

II. STUDYING MANUAL KNOW-HOW FOR TRANSMISSION PURPOSES: A METHODOLOGICAL ISSUE FOR PRACTITIONERS

II.1. The issue

The analysis of gestures in work situations, which has been the object of a recent review by Leplat (2013), is an important field of study in French literature on ergonomics and work psychology.

Chassaing (2006) has contributed to the definition and understanding of professional gestures by developing a hierarchical model that describes the organisation and structure of gestures learned on the job in the automotive sector. This work has made it possible to establish a clear distinction between the concepts of movement and gesture. In particular, she has provided a categorisation of professional gestures into four groups: (1) the gesture is mixed, as it "requires a sensory, cognitive and motor activity"; (2) the gesture is invested, as it is "intentional and oriented toward different purposes: the system, oneself and others"; (3) the gesture is situated; and (4) the gesture is constructed, as it is "the product of a history, a past and is continuously developing".

Gesture involves several dimensions: psychological, organisational, economic, biomechanical and cognitive (Bourgeois & Hubault, 2005). The study of musculoskeletal disorders, because they are often caused by repeated gestures, has led to a detailed study of the cinematic and motoric aspects of gestures (Vézina, Prévost, Lajoie, & Beauchamp, 1999). In the aviation sector, Aubert (2000) sought to understand what exactly makes

up the specificity of skills linked to the gestures of aircraft painters by analysing work situations, for a better understanding and recognition of this profession during an industrial process of reorganisation.

In the food industry, observation of meat boners for vocational training purposes (Ouellet, 2012) showed how the choice of variants of a gesture is linked to the nature of the equipment as well as to training, for example, the quality of the tool, or variants in the material (in this case, whether it was a left or a right back quarter that was to be deboned). Authier, Lortie, and Gagnon (1996) described a similar variability in the work of expert handlers: how they adapted their posture to the size, weight, or placing of the objects handled. These authors insist that expertise involves this capacity of adapting an activity to the context, and therefore also emphasise the necessity of examining gesture as an integral part of activity, as opposed to conducting limited musculoskeletal analyses.

Clot and Leplat's (2005) clinic of activity uses the crossed self-confrontation method as a conceptual tool for studying the development of professional gestures and individual and collective practices through reflexivity. This method has been applied to various cases of professional gestures, such as, amongst others, the gesture of braking a train (Fernandez, 2001), the gestures of grave diggers (Simonet, Caroly, & Clot, 2011), mainly for the prevention of musculoskeletal disorders. Those authors have observed the difficulty in accessing, analysing and transmitting the knowledge underlying such professionalised gestures. Thus, the multi-dimensional character – situated (Suchman, 1987), distributed (Brassac, 2008; Hutchins, 1995) and embodied (Varela, Thompson, & Rosch, 1991) – of the knowledge required for carrying out a professional activity would appear to require no further demonstration. The exact nature of the experience is at the core of the issue, as it is individual, unique and shaped by each person over a period of time and depends on the people and situations encountered and experienced. It is this subjectivity, specific to each person, which makes the task of passing on professional experience so difficult. Furthermore, such experience is also considered to be almost ineffable and, because of this strong tacit dimension, not easily transferable (Artemieva, 1980; Kornilov, 2014). Nevertheless, even if experience cannot be literally transmitted, it can be shared to some extent. That is why the tradition of socialisation practice (Nonaka & Takeuchi, 1995), such as professional mentoring (Castéra, 2008; Schön, 1983), is an option frequently used by the manual work sector to enable experts and novices to engage in face-to-face intellectual, social, and experiential sharing directly in the workplace. Unfortunately, the kind of training environment that makes it possible to provide a long period of overlap between the departing expert and the new arrival is less and less viable as a result of increasing time pressures and the mass retirement of experts. This demographical transition requires the replacement of the experts involved in the first industrial development, those whose careers began in the 1960s and 1970s. The challenge for organisations is two-fold: firstly, to safeguard the intangible cultural heritage present in the minds of its experts, and, secondly, to pass this knowledge on to newcomers. Thus, seeking and/or developing novel alternatives for

addressing this twofold issue of knowledge management for professional mass-training purposes is an urgent requirement.

II.2. Verbalisation of work activity

Analyzing the possibilities for creating or developing training systems for the transfer of professional knowledge, Shadrikov (1974) identifies three categories of objects in terms of their features: those that can be verbalised, those that can be represented in the form of visual images, and those with the so-called sensory features that are difficult to verbalise or represent graphically. According to Kornilov (2014), in the case of the transfer of professional experience, practical problems occur in different forms that are more or less easy to transfer by means of speech: tacit knowledge, individualised knowledge (which contains not only the features of the object but the particularities of the actions performed on it by a specific professional), unconscious stereotyped knowledge related to skills, heuristics, evaluation strategies, knowledge related to specific context, and so on. Kornilov (2014) showed that the problems that occur in professional interaction are determined, in some cases, by the presence of individualised knowledge, knowledge that, when identified with a single word or phrase, has different meanings for different workers.

In Europe, as in Russia, a range of techniques of verbalisation has been developed. They can be used to facilitate the verbal transfer of subjective experience at different moments of the action, and according to different types of instructions and settings. Among the best known are, the thinking-aloud protocol (Ericsson & Simon, 1980), or *post-hoc* verbalisations, including the self-confrontation interview (Theureau, 1992), the crossed self-confrontation method (Clot, Faïta, Fernandez, & Scheller, 2001), the "explicitation" interview (Vermersch, 1990), or the subjective re-situ interview (Rix & Biache, 2004). The method of "instruction to one's double" (Oddone, Rey, & Briante, 1981) is another technique that involves describing one's approach to work and instructing another operator as if he/she were a double. For further methods, the reader can refer to the book by Bisseret, Sebillotte, & Falzon (1999). Garrigou, Carballeda, & Daniellou (1998) also list commonalities in verbalizing know-how techniques:

- *"They avoid formulations involving explanation;*
- *They avoid rational and causal-type questions, and therefore the use of 'why' which will require justifications from the subjects rather than descriptions of their actions;*
- *They use interview methods that encourage descriptions of the action process;*
- *They produce questions that promote the systematic description of the sensory modalities and their different components (sight, hearing and taste, as well as kinaesthetic and olfactory aspects).*"

In Russia, some other types of verbalisation protocols have been developed, as, for example, (1) giving instructions asking individuals to explain where and how objects can be used whilst prohibiting certain types of

verbal descriptions, for example, those which refer to the size, color or material of objects,(2) setting a task to create a plan for certain activities in a verbal format and within a time limit,(3) facilitating the updating of instrumental experience by presenting a list of functional features to be ranked, compared or classified and so on (Kornilov, 2014). The problem of the verbalisation of knowledge encountered by professionals in their practical activity is also investigated through the identification of personality traits related to the verbalisation taking place in practical thinking, which is thinking related to action.

II.3. Methodological gap

The psychological verbalisation techniques cited above seek to investigate work activity, but they were not primarily developed for the practical issue of know-how transmission. They do not link the content of collected verbal data and the way in which they can be used for practical purposes. In the field of knowledge management (Earl, 2001; Ermine, 2010; Nonaka & Takeuchi, 1995), methods have developed over the past twenty years, essentially focusing on providing tools and techniques for structuring and presenting knowledge, but the use of video as a medium to convey expert knowledge remains a challenge. Some homemade videos are produced by trainers or field operators in the production industry to meet their needs for innovative teaching tools, but they generally use a prescriptive approach that shows "what-must-be-done" according to rules, thus missing out on the variability of actual practices that go beyond the prescribed. Furthermore, novices also need to share, feel and even "live" the experience in order to be able to fully grasp an expert's cognition.

To sum up, European literature proposes few practical methods enabling video-based data collection for transmission purposes in educational settings. The same assessment applies to Russian literature. Knowledge transfer in the workplace is investigated in psychology in terms of the specific psychological particularities of practical thinking and the verbalisation of its procedural characteristics, rather than in terms of an elaboration of a concrete methodology for studying professional gestures for educational transmission purposes.

On the basis of our empirical research within the context of the main French energy producer, we make the argument that using real cases of gestures, collected, analyzed and transmitted through video from the direct point of view of the expert, can provide an efficient alternative for both filling this methodological gap and answering the twofold requirements of the organisation. We present below a qualitative research method centered on the expert's perspective, which we have designed to render explicit the expert's tacit knowledge. Based on embodied (Varela et al., 1991), situated (Suchman, 1987), and distributed (Hutchins, 1995) cognition models, this method uses and combines principles of the Activity Theory, the Perceived Quality approach, visual ethnography, and verbalisation methods in order to analyse expert professional gestures for transmission purposes. The next section presents our main theoretical and methodological principles.

III. THEORETICAL AND METHODOLOGICAL BACKGROUND

III.1. Activity theories

In parallel to the French development of ergonomics centered on work activity (Leplat & Cuny, 1974; Ombredane & Faverge, 1955), activity theories centered on the subject appeared in the USSR in the early twentieth century.

Since then, many versions of activity theory have been developed worldwide (Bedny & Karwowski, 2004; Engeström, 2000; Nardi, 1996; Stetsenko, 2005; Von Cranach, Kalbermatten, Indermühle, & Gugler, 1982). Engeström's activity theory is particularly popular, having been developed to take into account organisational characteristics of the activity (such as the division of labour, tooling, and rules).

While theoretical work on Activity Theory is sophisticated, methodological approaches to its application in studying work activity lag behind. Our own research is based on the psychological structure of the activity developed by the Russian school of Activity Theory (Leontiev, 1978; Rubinstein, 1922, 1940) but makes little use of its philosophical aspects linked to personality, conscience, or emotions.[1]

Activity Theory in the Russian tradition has been developed primarily by Leontiev (1978) and Rubinstein (1922, 1940), who elaborated two somewhat similar versions of the structure of human activity. Generally, Activity Theory aims to render explicit the relationships between the different components of an activity, namely, motives, goals, tasks, actions, and operations.

In Leontiev's version, *motives*, interpreted not as a kind of experience of need but as a material or ideal object of need, determine the whole activity, which is carried out by means of actions directed by conscious goals. The expected result of activity, which is the *goal*, defines the actions necessary to reach it. However, *actions* are ultimately determined by the motive of activity. Indeed one activity can be completed by means of different actions, and one action can be a component of different activities. *Operations* are concrete ways to realise an action and correspond to conditions of activity. Thus, in the Leontiev's theory, motives refer strictly to the whole activity, goals refer to actions and operations refer to concrete situations.

Rubinstein's conception of activity structure is similar to the one proposed by Leontiev in the sense that the same activity components are outlined. However, according to Rubinstein, there is no strict correspondence between the motive and activity or between the goal and action. Activity-related motives and goals, unlike action-related motives and goals, usually have an integral nature, express a subject's general orientation and, thus, are called initial motives and final goals. At different stages of activity, activity-related motives and goals generate different specific motives and goals, which characterise actions.

1. Some of our theoretical choices have been guided by the wish to design a practical method that can be applied by practitioners other than researchers.

Both activity theories provide an efficient conceptual framework for investigating "human and environment" interactions, while Rubinstein's version is focused on the philosophical and theoretical developments of an activity linked to concepts of conscience, personality and the life of the subject.

In the context of both analyzing and giving a psychological description of a practical work activity, the components being evaluated are as follows: the motives that induce activity; the goals – conscious representations of future results to be reached; the subgoals – intermediate stages in reaching the goal; and the actions and operations carried out by a subject in order to reach the goals. To these should be added the tools used by the person or the organisation to transform the external environment.

Some of the components, such as operations, can be observed and recorded, while others, such as motives or goals, are invisible. These invisible components can be revealed and characterised only by means of techniques developed to analyze and evaluate subjective representations of individuals. The modes of investigation that we used to trace relationships between externally observable parameters of activity (movements) and their internal components (thoughts and so on) are presented below.

III.2. Subjective evidence-based ethnography (SEBE)

One of the ways of collecting observable components of an activity is by using video ethnography. This naturalistic approach enables the capture and study of flows of activity during real-life practice in the field. Over the past ten years, visual ethnographic methods and techniques have been expanding. They have been used by social scientists in various disciplines (sociology, anthropology, psychology, ergonomics), in order to observe and study human activity in a qualitative way (Goldman, Pea, Barron, & Derry, 2007; Heath, Hindmarsh, & Luff, 2010; Lahlou, 1999; Mondada, 2003; Pink, 2007).

As activity is distributed, the workers use not only their embodied competence but also a series of physical tools and instruments to transform material objects (Rabardel, 1997), mediating structures to operate cognitive operations (Hutchins, 1995). Other colleagues and various non-human entities are also involved in activity. Furthermore, action emerges in context: it is situated (Lave, 1988; Suchman, 1987). Consequently, when we try to reconstruct the action and understand what the human actor did, we need to account for all the contextual elements which contributed to the action. These elements cannot be recovered easily from the operator's memory alone. Therefore, we use video to bring the complete situation back to the operator at the time of recall; this enables the operator to point to the relevant elements that supported the action while it was happening. We use a *first-person perspective* capture to reconstruct the situation as it was seen by the operator at the moment of action, because, in complex situations, what was relevant for immediate action is usually what the operator paid attention to.

First-person perspective is provided by *subcams* (subjective cameras) (Lahlou, 1999), which are miniature video cameras worn at eye level by

the subject while he/she is performing his/her activity. In a second stage called "replay interview", the subject is asked to describe and explain her/his covert behaviour, as he/she remembers it, to the researcher while watching her/his own subcam recording. The technique of the replay interview is similar, in its aim, to well-known *ex-post* verbalisation techniques (see II.2), as they all seek to immerse the operator *ex-post* in his/her own activity, by confronting him/her with a track (not necessarily video) of his/her activity in order to make him/her verbalise her/his cognitive processes corresponding to earlier actions. The specificity of our approach is that it integrates the principles of Activity Theory and Perceived Quality Theory, and, furthermore, it uses first-person perspective recordings of the expert's activity in order to stimulate his/her memory, so as to take advantage fully of all of the elements of the techniques mentioned above. Thus, this technique, which entails the use of first person perspective digital recording as a basis for analytic *replay interviews* with participants, is called *Subjective Evidence Based Ethnography (SEBE)* (Lahlou, Le Bellu, & Boesen-Mariani, 2015). Several research teams now use or have developed customised first-person perspective recording tools similar to the subcam for studying activity in extreme settings and in training contexts (Myrvang Brown, Dilley, & Marshall, 2008; Omodei & McLennan, 1994; Rix & Biache, 2004). Such wearable devices for operators obviously provide practical advantages for practitioners and researchers who analyze work, by facilitating the task of data collection. Indeed, the subcam makes it possible to capture activities on film even while the subject is moving. Regardless of the location or the bodily movements, the device inevitably follows the operator's focus of attention and action, enabling to make a continuously situated recording of his activity. In this way, data can be collected without any outside observer; the operator is free to organise her/his activities and movements. But beyond this convenient aspect, we have noticed that the "subfilms" empower operators to recall very precisely and accurately what they did, thought and felt at the time of action, even some weeks after having experienced the real-life activity, probably because the subfilms feed the viewer with the exact context of action, attention focus and motor cues. One key advantage of SEBE is, therefore, its introspective "power" for triggering recall of lived experience. Another important advantage is its ability to provide the analyst with a detailed step-by-step understanding of the constituents of activity: goals, subgoals, determinants of actions, decision-making processes, and so on.

III.3. The perceived quality approach

The Perceived Quality approach (Nosulenko & Samoylenko, 2001) can be used to analyze both observable and subjective components of activity. This framework is useful in the analysis of practical activities taking place in real-world contexts, and in the identification of which elements of the environment are considered by individuals to be the most valuable in the course of achieving their aims. From this perspective, the definition of perceived quality can be formulated as follows: "*A set of subjectively relevant*

characteristics of the world and the activity, which comes about in the subject with the objective of attaining her/his goals" (Nosulenko, 2008).

It is impossible to define *a priori* the number of so-called "objective" components to be measured in the course of observations. We can only take an interest in those that are pertinent for the subject, the features that manifest themselves in the "perceived quality" of the gesture. The goal, then, consists in matching those components of perceived quality (in our case, the oral explanations given of the gesture by the operator– see section IV) with the observed components of the events (the professional gesture performed within a technical context).

The perceived quality approach begins with identifying the aspects of the object or system that are subjectively valuable for certain individuals in the course of the given activity. The strategy is to elaborate, and then empirically prove, a number of hypotheses concerning the parameters of actions. This assumes the inclusion of these aspects in the individual's perceived quality, and the setting up of an evaluation system based on them as they appear in open-ended individual evaluations. Which aspects of the artifact are responsible for determining these subjective characteristics will only appear in the course of careful examination of an activity. It is by confronting these evaluations with moments of actual activity and their description, using activity theory, that this will happen. For a detailed description of how this is done in practice, please refer to Lahlou et al., (2012), sections 10.2, 10. 3 and 12.3, and Le Bellu, (2011).

IV. FROM COLLECTION TO EFFECTIVE TRANSMISSION: METHOD AND PRACTICAL APPLICATION

This section provides an overview of the main steps and specificities of the methodological protocol we developed to study professional gestures. This method, called ECAST (Elicit, Collect, Analyse, Structure, Transfer), is presented stage by stage in this section and is illustrated by means of its application to one of the fifteen gestures used to develop and test our methodological principles (Le Bellu, Lahlou, & Nosulenko, 2010; Le Bellu, 2011).

The gesture used in the example, is called "plugging in a 380V valve power supply cell". It was performed in the company's main training centre by an expert operator, now an instructor, on a full-scale model of an installation used in the plants.

IV.1. Preparation stage

This stage involves organisation of the study and familiarisation with the activity to be examined, as well as the collection of a range of documents (procedures, handbooks, diagrams of the installation, training documents, and so on), selection of the expert by the organisation and informal interviews with the expert(s). This stage enables the analyst to become acquainted

with the aim and content of the activity to be studied. Selection of the place and time of data collection also takes place during this stage.

IV.2. Data collection protocol

IV.2.1. Principle

The purpose of this stage is to collect data that will provide an approach to a subjective experience embodied in a professional gesture.

To obtain a third-person perspective, a camera fixed on a tripod provides a contextual view of the setting. Given the physical constraints of the environment, the best location for the camera is selected in order to capture the working environment, the machine and tools handled by the operator. This external camera may be manned for zooming and reframing as the activity unfolds.

This contextual recording is accompanied by a synchronous first-person perspective recording, based on the SEBE paradigm described above. Operators wear a subcam, and as they act, a first-person perspective of their visual scope, soundscape (including speech), and manipulations is recorded.

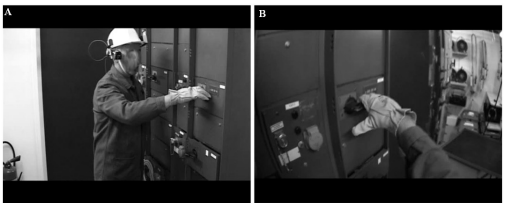
Video data collection is combined with a simultaneous verbal protocol, which we adapted from existing methods. This protocol, called "goal-oriented thinking-aloud" includes: (1) an introspective dimension: what the subject's goals are; (2) a descriptive dimension: how the subject achieves his/her goals; and (3) an explanatory dimension: what reasons lead the subject to act in a certain way. This instruction, although demanding, makes it possible to access the cognition of a gesture by providing the expert's rationale. In transmission, this will enable the learner to go beyond mere imitation of the gesture. The whole instruction is the following: "*Formulate the intentions that you pursue as you perform your gesture. And for each of these intentions explain both the reasons and the way you achieve this objective*". In addition, the operator is asked to verbalise those of his/her experiences that have led to good practices (knowledge developed over time, situations, experience, people met and other past experience) and/or critical points (warnings about hazards or risks that are not formalised in any documentation) that he/she considers important for novices. Following the principle of the Perceived Quality framework, the operator is free to choose whatever he/she considers worthy of comment. The operator is also encouraged to specify how he/she breaks down the activity and to what degree.

Our field studies showed that the success of this goal-oriented thinking-aloud protocol depends on a stage of mental preparation on the part of the operator, which occurs before the simultaneous verbalisation protocol. This mental preparation allows the operator time to think about how to explain the gesture *in situ* (with emphasis on aspects that are usually tacit), following a format that enables cognitive modelling of the gesture and, later, structuring of educational material. This step can be completed in pair work between the expert and a colleague or another expert. It was observed that discussions help to share practices, to externalise knowledge, and facilitate decision-making about how best to teach the gesture.

IV.2.2. An example of application

Figure 1 illustrates the data collection protocol described above by providing screenshots of the video recordings and transcriptions of commentary extracted from the recordings of the gesture "plugging in a 380V valve power supply cell". This figure provides a view of the same scene, at the same moment, from an external camera (Figure 1A), from the first-person perspective provided by the subcam worn by the expert (Figure 1B), and commentary provided according to the instructions of the goal-oriented thinking-aloud protocol (Figure 1C).

It should be noted here that this example does not involve specific manual skills, like those that are used in some professional gestures such as carving or painting, or gestures involved in specific attentional or diagnostic skills, such as driving or hunting. In this case, the movements are simple (pressing a button, turning a handle, pulling out a drawer) and any difficulty resides in the proper sequencing of operations. The experts focus, therefore, specifically on the cognitive aspects of the task, since explaining how to press a button would not appear problematic. In other settings, fine control of the movement can have implications for the final result (Vézina et al., 1999) or may lead to musculoskeletal trauma (Authier et al., 1996). In such settings, fine control is then the main focus of operators and analysts. This is a reminder that every activity is different, and that descriptions should focus on what is especially critical, otherwise they may appear lengthy or irrelevant to operators.



C *"… the next step is to turn on the power circuit. To do this, I will use the black handle here; I must put it upright. There is a risk of ejection of the drawer outward, so a risk of damage to the equipment and a risk for the persons operating in the vicinity. Whenever I manoeuvre the breaker, I stand to the side to avoid any injury in case of ejection…"*

Figure 1: Extract of video and verbal data collected through the application of the data collection protocol.

Figure 1: Extrait de données verbales et vidéo obtenues par l'application du protocole de recueil de données.

IV.3. Analysis of collected verbal and visual data

IV.3.1. Principle

In investigating the subjective experience of performing gestures, the analysis of verbal and visual data is an important stage. A set of practices developed within the scope of our approach ensures that the observational data (video recordings, technical parameters, analysis of prescriptions,

procedures, and other data) corresponds with the data describing the operator's subjective experience (verbalisations concerning the objects and the components of the perceived activity). These practices are as follows:

- analysis of subjective experience related to this activity: what an individual thinks about the various elements of the activity and how he/she describes them in his/her own words;
- analysis in terms of activity: making explicit components and to which objects of the world they are directed at;
- connecting the elements of the activity to the subjective experience, and understanding which aspects of the activity actually construct the experience.

The video recordings are used to trace externally observable behavior, in order to interpret individual and collective tasks that determine particularities in the use of tools, as well as to show specific features of professional activities and identify professional experience. Analysis and comparison of the verbalisations and the video tracks shows which tasks help the operator to achieve his/her concrete goals, under which conditions or using which tools; hence, what actions and operations are carried out during these tasks.

We consider the verbal data obtained from verbalisations to be representative, and therefore useful for highlighting perceptive qualities. The verbal data analysis we undertake involves a kind of a "bottom-up" approach, where important themes and categories emerge from data analysis of the texts. One advantage in this is that themes are not imposed by the analyst, but extracted from what participants report. Therefore, this approach avoids the pitfall of failing to pinpoint the operations or actions that are the most important for the participants in their professional activity. Our verbal data analysis is similar, to a certain extent, to the inductive content analysis (e.g., interpretative phenomenological analysis, Grounded Theory, and others (Willig, 2001)) that enables us to understand the participants' unique experience of the world. It can reveal divergence or convergence in the themes evoked by different participants. Our verbal data analysis is used to reveal the elements of the conscious subjective experience (e.g., perceptions, emotions, cognition, actions and operations) of individuals within their particular professional activity.

With this analysis in mind (see example below), a preliminary video editing of the gesture is made by the analyst for the next step, the replay interview. This provides a video of the activity in which the maximum amount of information regarding the gesture is retained, while episodes that are not directly relevant (such as preparation of the equipment, discussions, and so on) are removed. As for the different episodes of the activity, the analyst selects the perspective (first or third) that best highlights the operations that have been filmed. During the preparation of this video, the analyst constructs a global representation of the observed activity. He/she compares the contents of the video with the information gathered from the expert's preliminary verbalisations (during the preparation and data collecting stages) and from the analysis of available documents or training manuals. Thus, this analysis allows him/her to formulate some initial

hypotheses regarding the cognitive structure of the gesture and the importance of the various operations involved. These hypotheses provide a basis for a list of questions that may be asked during the replay interview. The duration of the video edit should not be very different from the actual length of the gesture. It is only after the replay interview (see next section) that the analyst will be able to undertake the video editing of episodes and scenes in depth, based on the perception of the expert.

IV.3.2. An example of application

The encoding of the subsequent tasks and operations takes into account the semantics and vocabulary used by the operator in his/her commentary.

The main goal

According to the expert's comments, the overall goal of the gesture analysed is *"to close a valve located on a remote site"*. This valve is operated by a nearby motor, but this motor is powered by cells whose controls are in a remote room: those controls are the objects of the current gesture. This *main goal* is broken down into a series of six *tasks* carried out by means of *operations* with/on *objects* in the system. In addition, for each operation, we identify the system area and the control objects involved, as well as the system feedback, critical points and/or good practices, wherever applicable. Below, we present an extract of the structure for the second task, derived from the analysis of the verbalisations.

Task 2: Power down the control circuit

This task requires four consecutive operations with/on the objects in the control unit area. Two of them are as follows:

Operation 2.2: Press the red buttons on the circuit breakers;
- Area 2:2: Control unit;
  - Object 2.2: Two circuit breakers;
  - Critical point 2.2: Press the two circuit breakers one after the other (verbal explanations are provided in the video);
  - System feedback 2.2: The three indicator lights go off (success);

Operation 2.3: Press the thermal relay button;
- Area 2:3: Control unit;
  - Object 2.3: Thermal relay;
  - Good practice 2.3: Check the operating condition of the thermal relay.

The expected result upon completion of task 2 is the following: "the power cut-out switch can be operated safely".

The whole analysis provides an initial hypothesis regarding the cognitive model of the gesture (see Figure 2 for the final model of this example-gesture).

IV.4. Replay interview

IV.4.1. Principle

The initial aim of the replay interview technique (see section III.2) is to allow for an accurate reconstruction of the operator's activity, by obtaining verbal information about the content of the components in his/her activity (goals, tasks, actions, operations) and the tools employed. When used for studying professional gestures, two specificities of the technique need to be noted.

First, the video of the expert's activity, when used as a medium to stimulate recall on the part of the expert, should be a mixture of first and third-person perspectives, selected and edited on the basis of the previously discussed stage of analysis. A visualisation of certain aspects of the activity provides the operator, through language, with the psychological tools needed to mobilise his/her attention, memory, representations and other cognitive functions. Moreover, in addition to this video, the cognitive model of the gesture, also based on the initial analysis, is submitted to the expert for feedback. The interview is video-recorded so that it can be reviewed in order to determine exactly what the participant is referring to during the commentary.

Secondly, since the process of externalizing knowledge and reconstructing the activity has already started during the data collection stage, at this point, the objective is primarily: (1) to obtain additional information from the expert, and (2) to ensure that the initial hypothesis concerning the gesture's cognitive structure concurs with the knowledge the operator wishes to transmit. Furthermore, a series of elements, which are not explicit in the operating instructions, but which are part of the local culture and the subjective experience of the gesture, can be mentioned and added. One such good practice is to stand to the side of the drawer: this ensures that, in case of a violent ejection, the operator will not be injured (see expert's comment in Figure 1C). The operator mentioned that an operator was once killed during this operation, and that this case is systematically mentioned to novices during training. In fact, the expert who explained the gesture to the authors showed them a distressing picture of the scene taken after that accident. This explanation was therefore included in the educational resource we designed. We see here how the material obtained through our method can be re-used for transmitting culture in the training program. Thus, after the interview, the data obtained (a partial transcription and possibly a selection of audio extracts to be added in the video editing) are then analysed in order to help to improve the cognitive model and the final video editing.

This whole process provides the analyst/expert operator dyad with an instrument for highlighting the most important components and distinctive features (the perceived quality) of the gesture to be transmitted. The cognitive model of the gesture, called a "tree of goals" (Figure 2), provides the foundation for structuring educational transmission.

IV.4.2. An example of application

After the hypothesis of cognitive analysis and the pre-video editing have been presented to the expert during the replay interview, the model is adjusted in accordance with the expert's comments. The cognitive model below was built for the application of the "plug in" gesture (Figure 2).

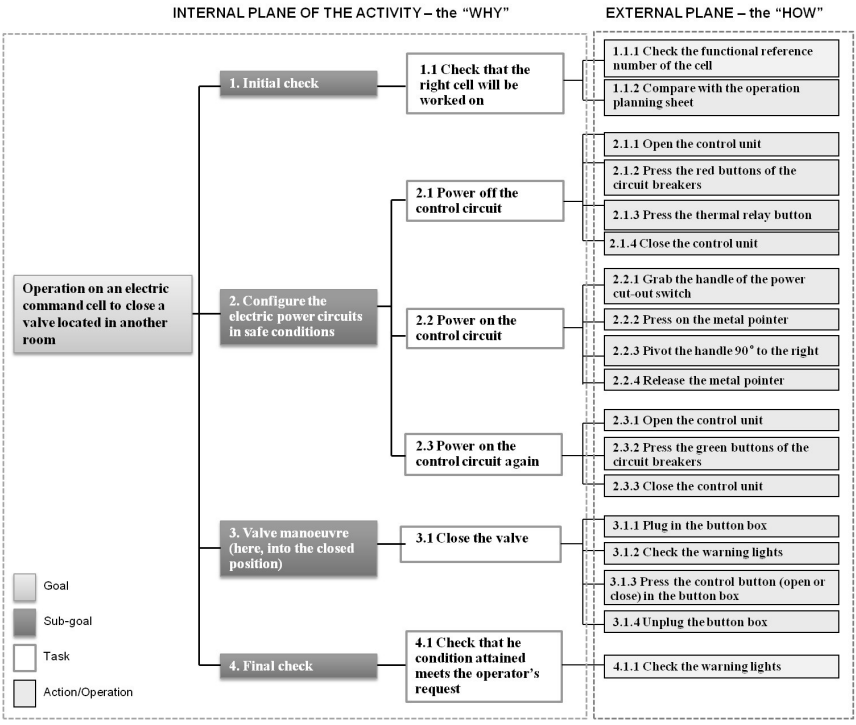


Figure 2: The cognitive model ("tree of goals") of the gesture "plugging in a 380V valve power supply cell".

Figure 2 : Modèle cognitif (« arbre de buts ») correspondant au geste « brancher une prise 380V à clapet ».

IV.5. Creating an educational real-experience based resource

IV.5.1. Principle

The last step of the method involves formalising and presenting the knowledge underlying the manual activity in a format that is suitable both for apprentices to use as a learning support and for instructors to use as a teaching device in situations where knowledge is being transferred, such as professional training settings. To achieve this goal, we designed a piece of educational software called Multimedia Platform for Apprenticeship

(MAP). Its structure is the same as the structure of the activity (the tree of goals) that was derived from the gesture analysis. Through this structure and its content, the MAP reveals the essential points of the gesture, from the expert's point of view. Thus, the apprentice using the MAP is put in the psychological position of perceiving the expert's perspective on the matter and can thus gain insight into the expert's process of reasoning and acting.

The MAP is organised into a series of three chapters. Each one focuses on a different dimension and level of detail of the professional gesture to be transmitted. The general purpose is to enable the learner to build a good mental model of the gesture, and to connect it with the sequence of operations as seen from a first-person perspective and re-positioned within the framework of the rationale of the gesture.

The tree of goals chapter (Figure 3) provides a detailed view of the activity by linking the subjective and the objective components structuring the gesture, from the goals pursued by the expert to the finest details and basic levels of operations performed to achieve those goals. Each operation is illustrated by a video clip from either a first-person or a third-person perspective, or from an edited version of both of these views. Each video clip includes the expert's commentary, recorded during the stage of verbalisation. The learner can therefore "dissect" and learn the gesture step-by-step, by "walking" through the tree of goals on his/her own and by "zooming in" on the various segments of the activity, in order to connect the more detailed information to the larger bird's eye view that contains the rationale and overall structure. In addition to this structure, good practices and vigilance points are identified and highlighted by means of specific icons. The experts' good practices – informally "the tricks of the trade" – correspond to the subtleties of the gestures that they have developed over a period of time. Vigilance points are complex and challenging aspects of the gesture; they require more attention because experts consider them necessary for the smooth running of the activity. It is essential to acquire skills to manage them for the successful and safe performance of the gesture. Finally, control points, which are feedback from the technical system, are identified and described in the analysis, as they are clues for situation awareness (e.g., lights that provide information on the status of the system) and for ensuring the proper progression of the activity.

The "full video" chapter gives an overview of a gesture carried out without interruption. This video has commentaries, from both first-person and third-person perspectives, and provides textual data corresponding to sub-goals, tasks, good practices and vigilance points. In this MAP chapter, the operational level is not taken into account. This resource is available in two forms, either as a self-help video, which can be viewed on a laptop, tablet or smartphone, or as a chapter integrated into the MAP software.

Finally, a third resource, labelled the "silent review video" shows the completion of a gesture without sound and at regular speed. It allows the apprentice to (re)view the gesture without any additional explanations. Thus, the rhythm of the activity can be learned. A resource such as this enables the apprentice to focus on the physical operations and the sounds

of the tools and machines. This chapter can be used either to discover the activity or review a gesture.

IV.5.2. An example of application

All the raw data collected and analysed provided the basic material for building a MAP organised around the cognitive structure of the gesture (Figure 3).

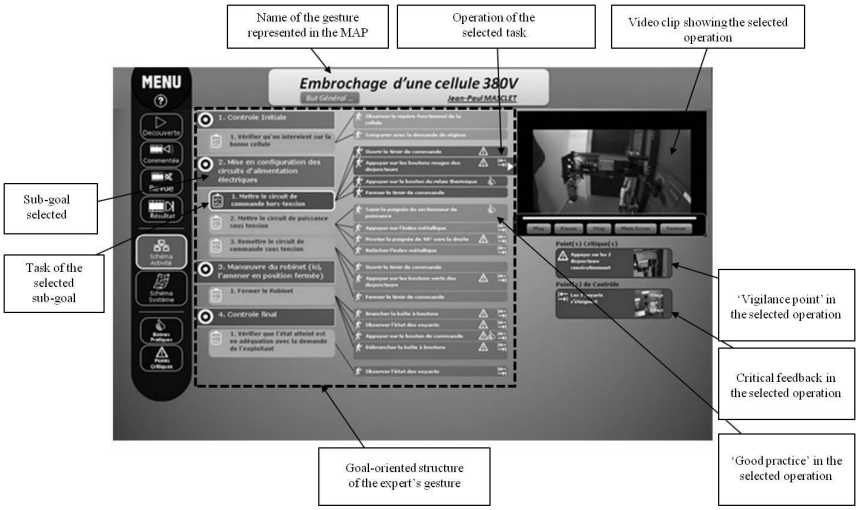


Figure 3: The "tree of goals" chapter in the Multimedia Platform for Apprenticeship (MAP).

Figure 3 : Le chapitre « arbre des buts » présenté sur la plateforme multimedia d'apprentissage (MAP).

V. DISCUSSION AND CONCLUSION

The primary goal of this research was to provide an answer to the real-world organisational problem of the mass-retirement of experts in the energy sector, and the situation of urgency that this has caused regarding skills capitalisation and transfer. A second goal was to provide a solution that could answer the needs of professional trainers for efficient, up-to-date training devices and tools, relayed via innovative media. Having examined current approaches to this question, it became obvious that a practical or concrete methodology providing an off-the-shelf solution for studying manual work practices for professional training purposes was lacking. On the basis of our analysis, and drawing on a multi-disciplinary approach (ergonomics, psychology, video ethnography, knowledge management), we have designed a method that adapts and combines the principles of verbal protocols, activity theory, a perceived quality approach and subjective evidence-based ethnography. This has resulted in the development of a

constructivist framework for collecting, analysing, and passing on experiential knowledge (good and hard practices, risky situations, and expert tacit knowledge) embodied in the activities of manual work, through video media, for professional training settings.

The method was designed in the context of empirical research carried out within the largest French electricity supplier. It is called ECAST (Elicit, Collect, Analyse, Structure, Transfer) and was designed to be centered on the expert's perspective. It provides theoretical, methodological and practical tools for practitioners to effectively collect and transfer the knowledge in training settings, through structured educational media. The completion of each stage of the method provides useful output for the completion of the next stage, much like a chain reaction. As a result, its originality resides in its capacity to use the raw material collected (videos, verbalisations, documents) both for analysis of the know-how underlying the activity and for the creation of a training product based on the expert's experience. The aim of this educational resource, known as MAP (Multimedia Platform for Apprenticeship), is not to offer a single, correct way of performing an action, but to provide a new way of representing the professional experience by enabling a novice to share the real-time experience of an expert through the first-person perspective provided by the subcam and accompanying explanations. MAP does not replace traditional professional mentoring practices, but in cases where such mentoring is no longer possible, it provides an overview of the know-how that would have been transmitted from the expert to the apprentice. Thus, we compensate for the loss of traditional socialisation practices. Such practices can be complimented with other learning methods in applied contexts (Fauquet-Alekhine & Pehuet, 2011; Pastré, 2005).

MAP tested successfully in the company's training centres. Improvement was noted in the practical sessions. Greater speed of execution was observed by trainers: the gesture could be performed twice by learners during the session with MAP, *versus* only once during the session without MAP. What is more, the method has been adopted and industrialised by the company. Five years after the first pilot was made, our method has captured about a hundred gestures and is now part of the standard toolbox of the corporate training division. The MAPs are increasingly being used within the company to train power plant operators. They could also be used as a basis for the development of local and national community platforms that would provide opportunities for reflection, discussion, clarification and exchange of work practices between experts as well as between novices and experts. This idea of collecting diverse ways of resolving situations and performing gestures could be a way of reinforcing the internalisation of know-how and the development of the novice's identity according to the principles of the communities of practice (Wenger, 1998). Diversity of practices, however, is an issue. It is not an issue for the MAP method itself, which can accommodate any practice and could provide variants, but it is an organisational problem. There are many ways of executing a specific activity, as noted in the literature on the subject (Authier et al., 1996; Garrigou et al., 1998; Vézina et al., 1999). It is not the gestures alone that are adapted to a specific context (for example, in our case, some small differences in the equipment and local culture were noticed between different power plants), but there

may even be disagreement between experts about what defines a "good practice". While this does not seem to be a problem for operators, who adapt a gesture to a situation, it is problematic for trainers and the training department, who are supposed to present "good practices". This becomes especially tricky when the gesture is taught in the context of a risky process in an industry that is under intense external scrutiny for safety management. We suggest showing trainees a variety of ways to execute the same gesture, in order to explain that reaching the goal is more important than the detail of the process and that professionalism is precisely the capacity to adapt intelligently to local contexts.

We adopted an inclusive approach to the "subjects". Involving a person whose activity is studied and video-recorded is essential because only he/she is aware of his/her internal states: this is why the SEBE approach prefers the term "participants", rather than "subjects" (Lahlou et al., 2015; Le Bellu, 2011), in order to emphasise the participants' roles as true contributors to – and collaborators in – the process of analysis. The MAPs are signed by an expert or experts, as this contributes to a reinforcement of the feeling of acknowledgement by the company. This organisational dimension constitutes the keystone of the new MAP-based training system, since it conditions the physical and psychological involvement of experts in the ECAST method. The analyst has the role of facilitator, providing the setting, in order to initiate and facilitate the internal process of expert knowledge externalisation. Thus, establishing a strong relationship of collaboration and trust is a second key element in this approach.

We think that this qualitative research method for capitalising and transferring the know-how embodied in professional gestures could be applied by other practitioners in many other sectors other than the specific high-risk industrial context of a power plant. Our method provides an efficient and practical framework for real-world research (Gray, 2013; Robson, 1993), providing a method for modelling work activity *in situ* from the perspective of the actor of the activity, through video-based techniques associated with specific verbalisation protocols. From this perspective, the method presented in this paper provides an original angle and framework, which may, we hope, contribute to the renewal of more traditional approaches to activity analysis, especially for the development and transfer of skills. Its main limitation of application lies in the type of gestures under consideration. In fact, it is well suited to sequential and motor gestures, whereas more complex gestures require further work. This is particularly true of joint activities involving a strong decisional component. The current method does not allow proper consideration of tasks distributed over time and between individuals. Thus, future research should consider how those kinds of activities could be approached both methodologically and theoretically by researchers using our method.

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