Activity analysis in sports situations by articulating heterogeneous data: reflections and perspectives for design engineering

David Adé, Nathalie Gal-Petitfaux, Nadège Rochat, Ludovic Seifert, Olivier Vors

Activités

17-2 | 2020
Le programme de recherche cours d'action

Activity analysis in sports situations by articulating heterogeneous data: reflections and perspectives for design engineering

David Adé, Nathalie Gal-Petitfaux, Nadège Rochat, Ludovic Seifert and Olivier Vors

Electronic version
URL: http://journals.openedition.org/activites/5517
DOI: 10.4000/activites.5517
ISSN: 1765-2723

Publisher
ARPACT - Association Recherches et Pratiques sur les ACTivités

Electronic reference
David Adé, Nathalie Gal-Petitfaux, Nadège Rochat, Ludovic Seifert and Olivier Vors, « Activity analysis in sports situations by articulating heterogeneous data: reflections and perspectives for design engineering », *Activités* [Online], 17-2 | 2020, Online since 15 October 2020, connection on 20 October 2020. URL : http://journals.openedition.org/activites/5517 ; DOI : https://doi.org/10.4000/activites.5517

Activity analysis in sports situations by articulating heterogeneous data: reflections and perspectives for design engineering

David Adé, Nathalie Gal-Petitfaux, Nadège Rochat, Ludovic Seifert and Olivier Vors

Introduction

1 In studies on the sources for expertise in sports, two major and contrasting conceptions clearly emerge. The first conception can be called "subject expertise," with its focus on the foundations of expertise, assumed to be mainly a given subject's cognitive and perceptual skills that equip him or her to achieve a high level of performance that is repeated over time (Ericsson, Krampe, & Tesch-Römer, 1993; Ericsson & Lehmann, 1996). These studies have greatly contributed to our knowledge on the cognitive and perceptual mechanisms involved in performance and expertise (Abernethy, Poolton, Masters, & Patil, 2008). However, they have often presented a fragmented conception of activity based on linear relationships between cognitive and perceptual dimensions and have tended to overlook the importance of the environment.

2 The second conception, which can be termed "coupling expertise," does not circumscribe expertise to the subject alone, but instead situates it within the actor-environment coupling (Davids, Hristovski, Araújo, Balague Serre, Button, & Passos, 2014). Recent works from this perspective have followed one of two approaches. Studies taking the ecological dynamics approach (Button, Seifert, Araujo, Chow, & Davids, 2020) attempt to show that expertise depends on the actor's capacity to achieve the task goal through perception-action loops that take into account a set of interacting constraints from the environment, organism and task (Davids *et al.*, 2014 *op. cit.*; Seifert, Button, & Davids, 2013). The other approach, which is ours, has been

defined by the course-of-action research program (CARP) (Theureau, 2004, 2006, 2009, 2015). CARP shares the idea of the inseparability of actor and environment with the ecological dynamics approach. Moreover, it focuses on the notion of "coupling expertise," and much of the research has confirmed that expertise emerges from circular relationships of co-definition between the actor and the environment (Bourbousson, Poizat, Saury, & Sève, 2011a; Sève, Nordez, Poizat, & Saury, 2013; Adé, Seifert, Gal -Petitfaux, & Poizat, 2017; Gesbert, Durny, & Hauw, 2017; Hauw, 2018).

3 As sports activity is often instrumented, research conducted from the CARP perspective has also attempted to account for the place and role of materiality in the structuring of expert sports activity (Gal-Petitfaux, Adé, Poizat, & Seifert, 2013; Adé, Seifert, Gal-Petitfaux, & Poizat, 2017 *op. cit.*; Rochat, Seifert, Guignard, & Hauw, 2019). These studies have emphasized the importance of the process of appropriating material artifacts as a key to expertise (Adé *et al.*, 2017 *op. cit.*). Indeed, they have shown that the process of appropriation comprises the integration of a material artifact into the actor's own body, its individuation and its transformation (Theureau, 2011). On this basis, the actor-artifact-environment triptych has been suggested as the smallest unit of analysis of expertise that we term "coupling expertise" (Adé *et al.*, 2017 *op. cit.*). This reduction makes it possible to account for the role of material artifacts in sports expertise by considering them as both constituting and constitutive of the actor-environment coupling. Although the appropriation process can be grasped from dimensions of an athlete's subjective experience—subject, of course, to methodological conditions—certain behavioral dimensions (e.g., biomechanical dimensions) of expert activity are relatively unmeaningful for the athlete. Therefore, bringing together conscious-verbalizable and unconscious behavioral data can provide a more granular account of an activity when the objective is the design of material artifacts. Indeed, "*a significant part of the motor actions of high-level athletes is highly automated, to the point that their biomechanical properties are sometimes based on processes inaccessible to the pre-reflexive consciousness of the actor and not verbalizable by him*" (Gal-Petitfaux *et al.*, 2013, *op. cit.*, P. 263). For example, although expert ice climbers use specific equipment (ice axes, crampons and quickdraws) to increase the repertoire of possible actions, the biomechanical components of their actions (e.g., flexibility in motor coordination to ensure greater adaptability during interactions with the equipment) remain inaccessible to consciousness despite their expert status. For this reason, CARP has begun to articulate data of different types to gain greater insight into the complexity of expert sports activity, particularly the interactions with material artifacts. Expert sports activity offers an excellent opportunity for this type of research because of the flexibility of expert motor behaviors (Seifert, Button, & Davids, 2013) and the importance of material artifacts in achieving high performances (Adé *et al.*, 2017 *op. cit.*). These two features offer researchers a privileged field for accessing a wealth of behavioral and experiential data that might well prompt new designs in sports equipment to optimize performance. We thus here present several methodologies, each offering challenges for both equipment design and CARP itself.

1. The experiential and behavioral dimensions of instrumented activity: challenges and methods for design

4 Three approaches stand out in the field of sports equipment design. Two of them are centered on tools ("engineering" approach) or humans (the "human factor" approach; for a summary, see Boff, 2006). The third is quite different and combines "user-centered design" (Norman & Draper, 1986) and "activity-centered ergonomics" (e.g., Récopé *et al.*, 2019). The first two look mostly at athlete-sports equipment interactions using data from physical measurements under experimental conditions, whereas the third approach places the "athlete-as-user" in an ecological situation at the center of the design process. By looking at athletes in real sports situations, "user-centered design" has developed a heuristic criterion in ergonomics: usability (Nielsen, 1993). Usability refers, of course, to utility (i.e., the match between the purpose of the material and that of the user interacting with it) but goes much further by taking into account the acceptability, efficiency, learning and pleasure felt by the user. "User-centered design" marks a break with the "human-machine" conception, and it has various methodologies for investigating usability throughout the design phase: questionnaires, simulated scenarios, discussion groups, and so on (for a summary, see Preece & Rogers, 2007). Yet, although these methodologies try to take into account the actor's viewpoint, they cannot gain access to what the user is actually living in a real situation—that is, his or her subjective experience in the situation and the appropriation of the material.

5 In ergonomics, the idea of examining the experiential dimension through "user experience design" developed outside the sports field (e.g., Hassenzahl, Law, & Hvannberg, 2006; Garrett, 2010). This approach has: (1) raised questions about methods based on a designer's predefined criteria, (2) highlighted the advantage of taking the real situation into account as an object of analysis, and (3) revealed the paradoxical situations in which certain performance criteria are met even though the users experience the tool as unsatisfactory or even unpleasant. "User experience design" therefore represents an advance over the "user-centered design" approach, and it is in this sense that CARP studies became interested in the instrumented activity of expert athletes, particularly the real-life experience of high-level swimmers, as a way of exploring the usability criterion (Poizat, Adé, Seifert, Toussaint, & Gal-Petitfaux, 2010).

6 Thus, to account for both the verbalizable-conscious and unconscious dimensions of expert sports activity, several CARP studies began to develop "observatories" from which first-person data (the actor's personal viewpoint on his or her lived experience) could be articulated with third-person data (behavior identified and analyzed by an observer but not necessarily making sense to the actor). These observatories are methodologically diverse, which is part of their interest. In this article, we describe any methodology as "articulatory" when it crosses heterogeneous data (i.e., experiential data and behavioral data) yet make no assumptions about the type of articulation.

2. Articulation of experiential and behavioral dimensions of activity: Challenges and methods for the course-of-action research program

7 The course of in-formation is a theoretical object of CARP that lets us bring together and connect experiential and nonexperiential levels (Theureau, 2006 *op. cit.*). From this perspective, the nonexperiential enriches the course of experience (the course of experience circumscribes an analysis of activity to what is meaningful for the actor) and the data from observing the body, behaviors or situations that did not give rise to experience for the actor. The course of in-formation therefore includes elements that do not belong to the actor’s pre-reflexive consciousness but that are “*nevertheless relevant for the actor’s internal organization at all times*” (Theureau, 2006 *op. cit.*, p. 50). The course of in-formation began to take on definition in studies on the design of driving assistance systems (Villame, 2004) and in the field of nuclear safety (Theureau *et al.*, 2001). These early studies might be described as pilot studies from theoretical and methodological points of view, and they confirmed the relevance of this theoretical object for gaining access to the crucial factors of performance or expertise in sports. For example, Poizat (2006) provided information on the articulation of the course of in-formation for table tennis players in match situations, using the tools of ethnomethodology. He used video recordings to identify nonverbal communications (a sign that announces an upcoming serve), facial expressions, postures or placements on the court and was able to highlight the structure of recurring interactions that were not perceived by the table tennis players themselves. Poizat is certainly the first researcher in the sports field to take “*a first step toward the theoretical object of the course of in-formation and did so by revealing the dimensions of the table tennis culture that the players had incorporated in their competition activity*” (Saury *et al.*, 2010, p. 22). This encouraged others in the field of sports expertise to articulate different types of data. Although the course of in-formation as a theoretical object extends the limitations in describing an actor’s course of experience, it is important to recall that it is based on respect for two theoretical assumptions of CARP’s enactive epistemology (Varela, 1989; Varela, Thompson & Rosch, 1993).

8 The first assumption is that all activity is situated, which imposes *in situ* analysis. The second assumption is that activity is autonomous and cognitive, which requires that priority be given to the actor’s viewpoint, underlining the primacy of the intrinsic. In other words, the course of in-formation calls for a prior analysis of the course of experience, with first-person data having priority and being central (compared to third-person data) and with respect for the real-life conditions for carrying out the activity under study. Although certain authors scrupulously follow these methodological principles (e.g., Saury *et al.*, 2010), others have deviated somewhat, never outright rejecting analysis based on the course of in-formation but preferring instead to call the method “mixed,” “multi-source” or “multi-level” (e.g., Hauw, Rochat, Gesbert, Astolfi, Antonini, Philippe *et al.*, 2016; Rochat, Seifert, Guignard, & Hauw, 2019; Vors, Cury, Marqueste, & Mascret, 2019) or describing their work as following the enactive approach (Rochat, Hacques, Ganière, Seifert, Hauw, & Adé, 2020). Based on the work of Quidu and Favier-Ambrosini (2014), the diversity of articulatory methodologies can be characterized. In a review of the literature focused on research combining first- and third-person data, the authors suggested two types of analysis to

distinguish these studies in the sports field: the first addresses the nature of the data and the second the modes of articulating these data.

9 The authors inventoried third-person data, such as mechanical and biomechanical data on athletes' gestures, postures and movements (e.g., Saury, Nordez, & Sève, 2010 *op. cit.*; Bourbousson & Fortes, 2012; Seifert, Wattebled, Herault, Poizat, Adé, Gal-Petitfaux *et al.*, 2014) or their physiological data (e.g., Berteloot, 2008; Vors, Marqueste, & Mascret, 2018; Vors, Cury, Marqueste, & Mascret, 2019). Concerning the mode of articulating the data, "*the articulation studies are differentiated by the status and evidential weight that they attribute to the two types of data*" (Quidu & Favier-Ambrosini, 2014, p.15). We therefore distinguish studies in which one type of data is subordinated to another type of data and those in which all data have equal value. In the case of relationships of subordination, the imbalance tends to favor experiential data for those studies claiming the course of in-formation (e.g., Gal-Petitfaux, Adé, Poizat, & Seifert, 2013, *op. cit.*). Yet sometimes the third-person data are prioritized, with the experiential data serving to complement and enrich the results (e.g., Seifert, Lardy, Bourbousson, Adé, Nordez, Thouvarecq *et al.*, 2017). In cases when the experiential data have primacy, they are used for sampling and identifying key moments in the activity that will then be studied using third-person data (e.g., Rochat *et al.*, 2019 *op. cit.*). Last, some studies have no relationship of subordination and attribute equal status and value to all the data (Seifert *et al.*, 2014 *op. cit.*).

10 These distinctions in the type of data and how to articulate them are useful for characterizing the various methodological options, but the theoretical assumption of the situatedness of activity suggests the need for a third analysis: the conditions for collecting and processing the data. On this point, we can distinguish studies conducted: (1) in real situations (e.g., Saury *et al.*, 2010 *op. cit.*; Gal-Petitfaux *et al.*, 2013, *op. cit.*) and (2) in what we call "controlled environments." Real situations are faithful to the training or practice environment, whereas in the controlled environment the researcher modifies its characteristics to facilitate the capture of certain third-person data while remaining as close to the ecological conditions as possible. This was, for example, the case in the study by Pouponneau, Poizat, Gal-Petitfaux and Adé (2011), who collected biomechanical data from ice climbers by having them make repeated strikes on an extruded polystyrene block fixed to an indoor climbing wall using different ice axes.

11 Despite their methodological and articulatory diversity, two common points unite these studies on sports expertise. The first is that they all conduct research within CARP, using first-person data collection methodologies to document the pre-reflexive consciousness of athletes-as-users. The second is that all seek to gain insight into the dynamic complexity of human activity in real situations or controlled environments. It nevertheless should be noted that recent developments in the articulatory methodologies reflect CARP's ongoing evolution, particularly around the increasingly diverse nature of the data and the modalities for articulating them. This methodological evolution merits further examination, especially in relation to CARP's theoretical hypotheses, to advance discussions on the program's scientific interest.

3. Three illustrations of articulatory methodologies that aid design efforts

12 In this section, we present three studies (in trail running, swimming, and ice climbing) and their methodologies concerning (1) the data collection conditions, (2) the nature of the data, and (3) the modalities of data articulation. These studies are distinguished by the design object and their articulatory methodology (see Table 1), and our aim is to point out the advantages, limitations and potentials as design aids within the CARP framework. We believe that the evolution in methodologies has raised important questions about the methods for designing sports equipment and the athlete-researcher-designer relationship. It also seems to have heuristic scope for analyzing work situations having similarities to sports situations.

Table 1: Synthesis of the observatory for three illustrative studies.
Tableau 1 : Synthèse de l'observatoire des 3 études illustratives

Discipline sportive	**Objet de la conception**	**Conditions de recueil des données**	**Nature des données**	**Modes d'articulation des données**
Trail	Sacs de portage et d'hydratation	Environnement contrôlé	Données d'expérience ; Données cinématiques	Données d'expérience comme majeures ; Données cinématiques comme complémentaires
Natation	Dispositif technologique de mesure des résistances actives	Situation réelle	Données d'expérience ; Données biomécaniques	Données d'expérience comme majeures ; Données biomécaniques comme complémentaires
Escalade glaciaire	Piolets	Environnement contrôlé	Données d'expérience ; Données cinématiques	Équilibre statutaire entre les données

3.1. The articulation of heterogeneous data as a design aid from a "first-person sampling" approach in a "controlled" environment: the study of hydration packs in trail running

3.1.1. Descriptive summary of the study

13 We present here a study that integrates phenomenological and behavioral data for the analysis of instrumented trail activity—more specifically, the appropriation of carrying and hydration systems. Trail running races take place outdoors on marked trails in semi-autonomy. These races require the trail runners to be self-sufficient between refreshment points, which implies that they carry all needed equipment (sufficient energy and water reserves, warm and waterproof clothing, first-aid equipment, mobile

phones). This activity is thus instrumented and the assumption is that the interactions with the equipment provoke perceptions, concerns, and behaviors related to the physical characteristics of the carrying system and the environment. An earlier study had focused on the discussions on specialized forums and found that certain carrying (e.g., backpacks, belts, etc.) and hydration (e.g., water bottles, water bags, etc.) systems were sources of negative experiences particularly linked to the sloshing and noise of the liquid in its container (Rochat, Hauw, & Seifert, 2018). Indeed, the challenge for these systems is to be transparent; that is, to interfere as little as possible with the runner's movements and to have a good level of usability. We therefore sought to investigate the appropriation of trail equipment in greater detail via the articulation of first- and third-person data.

3.1.2. Description of the method

14 We present the method in three stages in order to focus successively on the articulation of heterogeneous data with a view to design: the conditions for data collection, the nature of the data, and the articulation of the data. First, the condition for data collection was a controlled environment. The protocol reproduced a trail training situation during which several carrying and hydration systems were tested (see Rochat *et al.*, 2019 *op. cit.*). Nine seasoned trail runners performed five repetitions of a three-kilometer loop in a natural environment. This loop was chosen because it included typical racing segments like downhill, uphill, technical parts, and more rolling parts. Indeed, we sought to "reconstruct" a route that comprised the typical characteristics encountered while trail running. For each trial, participants wore a different carrying and hydration system. We applied the following conditions, a backpack with: (i) a vest bag with full gourds at hip level, (ii) full rigid gourds on the chest straps, (iii) half-full rigid gourds on the chest straps, (iv) half-full flexible gourds, and (v) a water bag placed on the back (see Figure 1).

Figure 1: Illustration of the backpacks and hydration systems tested for this study.
Figure 1 : Illustration des différents systèmes de portage et d'hydratation testés pour cette étude

15 Second, the nature of the data was experiential and kinematic. We collected course of experience data from self-confrontation interviews conducted after the race. Based on traces of past activities (i.e., photos of participants on departure and arrival and when putting on the backpacks, and the carrying and hydration systems were made available for the interview) and information about the route (i.e., the map, the plan and photographs of the route), these interviews sought to characterize the phenomenological experience of the trail runners in relation to the carrying and hydration systems, but not exclusively. We also sought to take into account other

aspects of the activity (e.g., energy management and physical sensations) that the participants reported. In addition, in order to "quantify" the sloshing they felt, the participants were equipped with inertial units placed at hip level, at the bottom of the backpack and on the two chest straps to acquire data on vertical accelerations.

16 Third, the experiential data was the priority for the data articulation, and the kinematic data was complementary. Articulatory data processing took place in three stages. First, based on the lived experience of the runners, a macroscopic variable was identified that was then enriched by analyses at the behavioral level. To do this, triadic semiotic coding (i.e., actions, perceptions, concerns) was conducted on the courses of experience to first identify the elementary units of meaning for each runner. This helped characterize the typical perceptions linked to the carrying and hydration systems. The typical perceptions were aggregated in order to (1) qualitatively document the uncomfortable features of each system and (2) track their temporal emergence according to the trail characteristics. The runners perceived the sloshing to be uncomfortable. We next identified on which parts of the trail the sloshing became salient for them in order to target the analysis of the vertical acceleration signals on these parts. The perceptions of sloshing in the courses of experience emerged prominently on the flat and low-tech part in the first half of the trail. We therefore sampled the behavioral data by processing only the vertical acceleration signals recorded in the first half of the trail. We then quantified the sloshing at the behavioral level by measuring (1) the extreme values of vertical acceleration for each of the oscillators at the runner's hip, the back of the backpack and the left and right straps, and (2) the vertical acceleration couplings between the runner's hip and the carrying system (i.e., hip-backpack couplings, hip-right strap, hip-left strap). We thus identified the modes of coordination between the runner and the carrying system (i.e., in-phase, anti-phase, phase shift), which reflected the acceleration couplings between them.

3.1.3. Summary of results

17 The main results showed that the perception of the carrying and hydration systems fluctuated according to the characteristics of the environment, with the systems perceived as uncomfortable (e.g., feelings of weight, sloshing, friction, etc.) in the flat and not very technical parts of the trail. However, in the technical parts (e.g., uneven trails, steep descents and climbs), the carrying systems became transparent because the runners were focused on the properties of the terrain. Also, the runners did not perceive the carrying and hydration systems in the same way, with some systems more appreciated than others. Indeed, the participants felt a significant and uncomfortable sloshing at the straps when full gourds were placed there, and these sloshing sensations were confirmed by the behavioral data: the peak vertical acceleration values were significantly higher than in the other conditions. In addition, the accelerations of the runners' hips and backpacks were in anti-phase, suggesting that the two oscillators accelerated simultaneously in opposite directions (i.e., a runner's hip accelerated upward and the backpack accelerated downward or vice versa). Conversely, the participants described the vest bag with the gourds at the hip as comfortable and barely or not felt by them. This transparency of the vest bag was congruent with the behavioral data because the acceleration peaks were significantly lower than in the other conditions. Also, the accelerations of the hips and backpacks were in-phase,

suggesting that the two oscillators accelerated simultaneously in the same direction (i.e., a runner's hip and the backpack both accelerated upward or vice versa).

18 These results from the analysis of heterogeneous data in a situation of a "controlled" environment can provide useful indications for designers. Indeed, although the content from feedback forms is widely used as a design aid, it is a macroscopic synthesis that reflects an overall impression of the material, which can sometimes prove to be imprecise and not very specific with respect to the characteristics of the environment. Thus, the more detailed analyses of experience and behavior provided deeper insight into how the trail runners interacted with the equipment in various situations (e.g., in terms of degrees of trail technicality). In other words, a detailed analysis of the transformations in the trail runners' courses of experiences and their behavioral manifestations made it possible to report "in real time" on how the users perceived and appropriated the material.

19 In conclusion, the methodology for articulating data in this study did not accord equal status to the experiential data and behavioral data. In fact, the experiential data on the sensation of sloshing helped identify and qualitatively document the variable that confirmed the sloshing through the behavioral data on motor organization, which ultimately enriched the experiential data. In addition, the data from the courses of experience also revealed other annoying features of the carrying systems (i.e., the sound of the water in the gourds, sloshing against the backpack straps, the tube for the water pocket, etc.), thus demonstrating that the behavioral data provided only partial information on the discomfort induced by the carrying and hydration systems. However, each system was carried for only a short time because of how the researchers defined the environment and the constraints on acquiring the behavioral data, and we therefore could not investigate how interactions with the system would evolve over prolonged use, where, for example, fatigue might impact the interactions. Concerning the methodology for articulating heterogeneous data in the analysis of the instrumented activity, future perspectives for research and generalization might include (1) capturing the data from lived experience more synthetically and macroscopically, such as by devising a scale to measure a system's perceived opacity/transparency, and (2) investigating the interpersonal differences in running patterns related to the system's perceived discomfort. This option would therefore impact the choice of the type of behavioral data because it would have to take into account other biomechanical parameters involved in trail running activity (e.g., stride frequency or trunk inclination).

3.2. The articulation of heterogeneous data as an aid to the design of a technological device: the study of an evaluation of swimming performance

3.2.1. Descriptive summary of the study

20 Improving performance factors is a constant concern for top coaches and swimmers. The protocols for evaluating biomechanical factors is a particularly well-developed research sector (e.g., Toussaint, & Truijens, 2005). One of the characteristics of these protocols is that they often involve instrumenting the swimmer in order to collect kinematic (e.g., spatiotemporal characteristics of movement) or kinetic (e.g., forces exerted on water by the swimmer; Chollet, Madani, & Micaleff, 1992) data. Although

these studies have provided insight into performance factors and led to improvements, they have not focused on the swimmers as they interact with the instrument of evaluation.

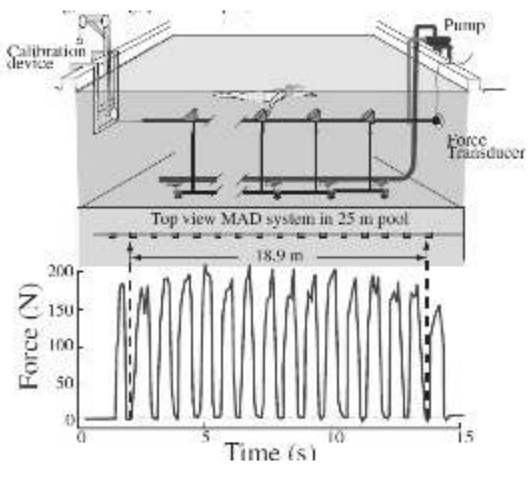
21 The aim of our study (Gal-Petitfaux *et al.*, 2013 *op. cit.*) was to examine high-level swimmers' courses of experience during a biomechanical performance assessment protocol with the aim of contributing to the design of new devices. We specifically sought to determine how the swimmers adapted to wearing a device, whether it affected their usual swimming activity, and ultimately whether the device evaluated what it was designed to evaluate

3.2.2. Description of the method

22 The method is presented in three stages in order to focus on the articulation of heterogeneous data with a view to new designs: the conditions for collecting data, the nature of the data, and the articulation of the data. First, data were collected in real-life situations. The study examined the courses of in-formation of three high-level swimmers, Marc, Luc and Paul, using an underwater technological device often used for training and biomechanical evaluation: the MAD system for measuring active drag (Toussaint, van der Meer, de Niet, & Truijens, 2006). This device measures the active drag of the upper limbs for each stroke cycle via force sensors and deduces the resistive forces exerted by the water. The swimmer's forward movement is dependent on the ability to overcome the resistive forces through the production of propulsive forces with arms and legs. Given that at a constant speed the propulsive forces are equal to the resistive forces (Newton's equation), measuring propulsive forces indirectly informs on resistive forces.

23 A pole was placed in a 25-m swimming pool 80 cm underwater with 16 wedge-shaped pads fixed perpendicular to the swimming axis and spaced 1.35 m apart. Each pad contained pressure sensors to measure the swimmer's active resistance: at each arm cycle, the swimmer pushed on a pad to advance and the force produced at a point on the hand was then recorded by a gauge located at the end of the pole and transmitted by a pressure sensor (Figure 2).

Figure 2: Overview of the MAD system with the swimmer's force (N) recorded on the 16 push-off pads. This figure was used with the permission of H.M. Toussaint and K. Vervoorn, 1990.
Figure 2 : Vue d'ensemble du M.A.D. System et de l'enregistrement des forces (N) du nageur sur les 16 cales. Cette figure a été utilisée avec l'autorisation de H.M. Toussaint et K. Vervoorn, 1990



24 The designers' instructions were as follows: (1) the swimmers perform ten 25-m laps starting in the water, with pre-established incremented speeds; (2) they swim each lap faster than the preceding lap and at a constant speed to reach maximal speed by laps 9 and 10; and (3) after each lap they have a nearly complete 3-min recovery so that they can increase their speed in the upcoming lap. At the end of the ten laps, each swimmer participated in a self-confrontation interview about their lived experience during the evaluation protocol.

25 Second, the nature of the data was experiential and biomechanical. This made it possible to document the swimmers' courses of in-formation and determine how they appropriated the technological device over the incremented speeds in the objective of possibly re-designing the protocol to better evaluate the biomechanical factors of performance.

26 The biomechanical data were taken from audiovisual recordings of the swimmers' behaviors using two cameras (one aerial and fixed, the other underwater and mobile), with measurements of the stroke rate (i.e., number of arm cycles per minute) and the hand force applied on each pad throughout the protocol (propulsive resistances to produce the required constant swimming speeds).

27 Data on the swimmers' experiences were collected from the self-confrontation interviews conducted within two hours of the assessment protocol. Faced with the audiovisual traces of his behavior, each swimmer with the researcher viewed the ten successive laps from the aerial and/or underwater view of choice. He was invited to document his actions during each lap (What are you doing at this precise moment?) by explaining his concerns (What are you trying to do? What is your intention at this moment?) and perceptions (What are you focusing your attention on? How do you feel at this moment?).

28 Third, the mode of articulating the data (1) prioritized the experiential data and (2) was based on a relationship of subordination, with the biomechanical data completing and enriching the experiential data to document each swimmer's course of in-formation.

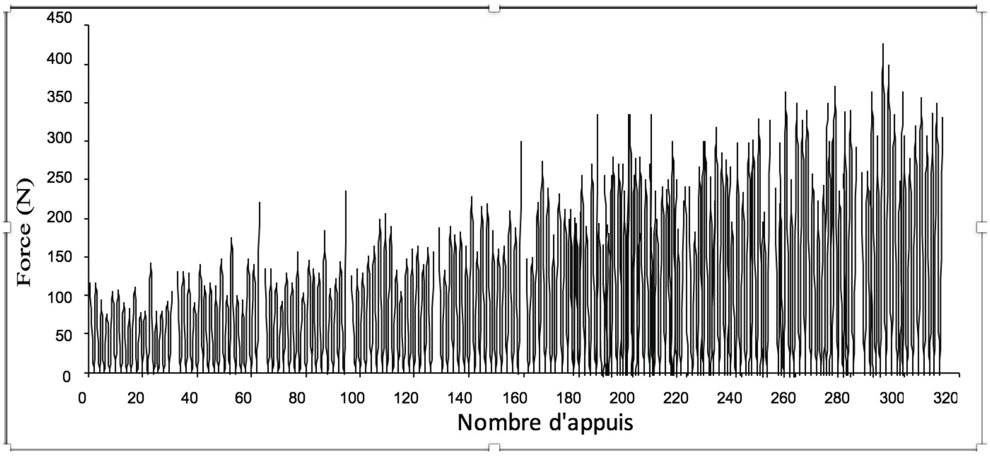
29 Thus, the experiential data were used to identify the course of experience of each swimmer: his significant actions at an instant t, his perceptions (what he was looking at or felt when he put his hand on the pad) and his concerns (i.e., the engagement stemming from his perceptions, what he sought to do when he put his hand on the pad) at the same time. On this basis, each component of the sign was analyzed to identify groupings with a "family resemblance" (Rosch, 1973) in order to extract typical actions, perceptions and concerns (Table 2). This treatment made it possible to identify differences/similarities for the swimmer across the three speeds prescribed by the designer (postures and swimming movements; ease or difficulty/discomfort linked to pressing on the pad; sensations of support to produce the propulsive resistances).

Table 2: Typical characteristics of Martin' course of experience (typical actions, typical perceptions, typical concerns) during slow speed laps.
Tableau 2 : Caractéristiques typiques du cours d'expérience de Martin (actions-type, perceptions-type, préoccupations-type) lors des passages à vitesse lente

Composantes du signe	**Cours d'expérience de Martin**
Action-type	Pose sa main sur une cale.
Perception-type	La cale suivante. Sensation de devoir modifier sa prise d'appui par rapport à sa nage habituelle.
Préoccupation-type	Cherche à avoir la main complète sur la cale, à la positionner correctement sans s'agripper dessus.

30 The biomechanical data were useful for examining the convergences/divergences in the experiential data as a potential design aid. Their analysis consisted in evaluating whether the values of the exerted forces and stroke rates differed (1) between the 16 pads for the same lap and (2) between the ten laps (Figure 3). The following tests were performed for each swimmer: a multivariate analysis of variance (MANOVA) to study the effects of laps and pads; a non-parametric Friedman test analyzing the combined effects of laps and pads on the force values; and an intraclass correlation test (Bland & Altman, 1996) to measure the reproducibility of the force on the 16 pads across the ten laps.

Figure 3: Typical formation of Martin's force exerted on each pad over the ten laps.
Figure 3 : Distribution-type des forces exercées par Martin sur chaque cale au cours des 10 passages



31 The swimmers' courses of in-formation were reconstructed for each lap and then compared by matching the action-types, perception-types, concern-types and force distribution-types exerted on the pads.

3.2.3. Summary of results

32 The articulation of the biomechanical and experiential data revealed convergences and divergences in how the swimmers organized their swimming activity, according to

each speed prescribed by the designer. This summary is structured in three stages: convergence of the data, divergence of the data, and perspectives for conception.

33 First, the convergences in the data revealed a disturbing effect of the pads on the swimmers' activity at extreme speeds. The articulation of biomechanical and experiential data revealed a "pad effect" that (1) disrupted the swimmers' interactions with the device and (2) was significant at extreme speeds (slow: laps 1 to 3; maximum: laps 8 to 10), and also (3) was revealed by the experiential data and (4) were objectified and confirmed by mechanical analysis. Although the swimmers followed the instructions to swim at a constant speed over each lap, which should have resulted in constant propulsive forces, the results showed that they modified their usual swimming in order to precisely place their hands on the pads, and this was confirmed by the constant irregularity in the amplitude of force on the pads. At extreme speeds, the swimmers' force graphs were convergent (same irregularity) and their typical concerns were similar: essentially, correctly placing the hands on each pad ("I keep thinking I need to look where the other pad will be, otherwise I might miss it" (Luc); " There I'm trying to position it (the hand)" (Martin). This shared concern of adapting movements around the pad was actualized by different actions: the swimmers stated that they had to modify their usual way of swimming to adapt to the device: for example, skip the phase of arm extension and shoulder engagement to push on the pad (Martin), reduce the elbow angle of flexion to adjust to the pads aligned on the pole (Paul), and change the head position (Luc).

34 Second, the divergences in the data revealed the swimmers' behavioral adjustments that were not meaningful to them. The articulation of the data revealed that at fast speeds (laps 4 to 7), the biomechanical data (objective exerted forces) were discordant with the experiential data (concern about the desired intensity on the pads and the subjectively associated sensations). There was a divergence between the swimmers' sensations when they manually pressed on the pads and the recorded pressures. Although Martin's typical concern, for example, was to press hard and fast on the first four pads and then maintain the acquired speed on the last pads, the force graphs did not match his sensation: they showed strong pushing on pads 6, 7 and 8, then 14 and 16, revealing that the swimmer did not perceive the sensation of exerting strong pressures again on the pads at the end of the 25 meters. Paul, on the other hand, was strongly focused on the central pads with the sensation of pressing hard and regularly, while his graph showed irregular pressures recorded on these pads. The biomechanical data provided access to subtle behavioral adjustments that the swimmers were not aware of. At the fast speeds (laps 4-7), the device was better appropriated by the swimmers, thus fulfilling its function of evaluating resistive forces.

35 Third, the articulation processing suggested possibilities for redesigning the evaluation system. Articulating the experiential and biomechanical data highlighted the process of appropriating the MAD system that emerged from the swimmer-system interaction, which varied with the imposed speeds and was not expected by the designer. The swimmers were forced to modify their usual swims to adapt to the physical, spatial and temporal constraints of the device and comply with the swimming instructions.

36 These results reflect the mediating role of the technological device in the swimmer-evaluation situation coupling. They do not call into question the relevance and effectiveness of the MAD system, which has been proven effective in evaluating the

biomechanical factors of swimming performance. But they do suggest possibilities for redesigning the evaluation situation.

37 The first possibility would be to make the system's physical characteristics modifiable. For example, the unvarying spatial positioning of the pads requires swimmers to produce a constant swimming stroke length (A) throughout the protocol and to increase their stroke rate (SR) to increase swimming speeds (V = A x SR), while in a natural situation swimmers increase A and SR in an optimal ratio to increase their swimming speed. The protocol required them to produce a constant speed in each lap and at each speed, and speed is the product of SR and amplitude (V = A x F). But we found that the recorded (As) and (SRs) were irregular, which suggests that the system should be modified, with perhaps a change the inter-pad distances during extreme speeds (slow and maximum) so that the swimmers can produce stroke lengths that feel close to those produced in normal swimming. The second would be to include a phase in the evaluation where the swimmers can assess their own activity to ensure that they no longer have feelings of discomfort and that the system has become transparent to them (Lenay, 2006).

38 This study identifies three contributions of data articulation. The first is that the reliability of the data was strengthened by the convergences between the biomechanical and experiential data: the feelings of discomfort in adjusting the hands on the pads at extreme speeds agreed with and confirmed the irregularity of the force amplitudes recorded at the same time. The second contribution is that the experiential data enriched the biomechanical measures by revealing the processes underlying the production of propulsive forces with each speed increment: the experiential data (actions, perceptions and concerns described by the swimmers) facilitated the interpretation of the measurements. The third contribution concerns the divergences in the data: the biomechanical data filled in the gaps in the course of experience for those automatisms and behavioral adjustments that were outside of the swimmers' awareness. A limitation of the temporal conditions of data collection should be mentioned: the instrumented context of the MAD system limits the reliability of the data with regard to appropriation, as revealed by this study. This suggests that swimmers should appropriate the MAD system before being evaluated (sufficient number of laps to guarantee good sensations and inter-pad force and stroke rate consistency).

3.3. The articulation of heterogeneous data as an aid to design from an "appropriation"-centered approach: Effects of the type of ice axe and fatigue on expertise in using an ice axe on an icefall

3.3.1. Descriptive summary of the study

39 Historically, the mountaineering axe served as a cane for mountaineers who could lean on the spike (Figure 4, ice axe A) and, when the slope was too steep, plant the blade in the ice and pull themselves up by the handle. With increasingly steep icy slopes and icefalls being climbed, ice axes were built with inclined blades to facilitate anchoring, a grip on the handle to facilitate holding, and a curved handle to anchor the top of ice protrusions (see Figure 4, ice axes B and C). The increasing popularity of competition in ice climbing and dry-tooling (see Figure 4, ice axe D), which is climbing on rock without

ice using ice axes and crampons, has considerably changed the practices and shape of ice axes.

Figure 4: Four types of ice axe with a more or less curved handle depending on use (from left to right): mountaineering (A), gully (B), icefall (C), dry-tooling (D)

Figure 4 : Quatre types de piolet dont le manche est plus ou moins incurvé en fonction de l'usage (de gauche à droite) : alpinisme (A), goulotte (B), cascade (C), dry-tooling (D)

40 Thus, the aim of this study (Pouponneau, 2015; Rouard, Robert, & Seifert, 2016) was to determine the criteria of expertise in ice axe striking by examining the links between the physical characteristics of different ice axes. The designers consider the gully ice axe (ice axe B in Figure 4) as the most versatile and suitable for beginners because it mainly requires arm movement and is easy to pull out of the ice. Our study was designed to determine whether the ice axes more specific to icefall climbing (ice axe C in Figure 4) and dry-tooling (ice axe D in Figure 4) required different types of strike and were more difficult to appropriate.

3.3.2. Description of the method

41 The method is presented in three stages in order to focus on the articulation of heterogeneous data with a view to design: the conditions for collecting data, the nature of the data, and the articulatory processing of the data. First, data were collected in a controlled environment. Our study involved ten expert climbers. The influence of the type of ice axe was tested by comparing the kinematics of movement and the lived experience of three series of 30 strikes performed with the gully, icefall and dry-tooling axes (Rouard *et al.*, 2016 *op. cit.*). The strikes were made on a 100 x 80 cm XPS extruded polystyrene block hung on a climbing wall (see Figure 5) to simulate a block of ice. To more closely reproduce an ecological context, the climbers were suspended from an ice axe in the non-preferential hand, feet on footholds 30 cm from the ground, and the strike was carried out with the preferential hand. Note that only climbers whose preferred ice axe was the Nomic icefall from Petzl© (Piolet C, Figure 4) were included in this study.

Figure 5: Experimental device for strike testing in simulated ecological conditions.
Figure 5 : Dispositif expérimental pour le test de frappe en condition écologique simulée

42 Second, the nature of the data was kinematic and experiential. We collected kinematic data to obtain spatiotemporal information on the movements related to the criteria for ice striking expertise pre-established by the axe designers (see Table 3, Column 2). The kinematic data were collected using a system of eight optoelectronic cameras (VICON) recording the positions of 19 reflective markers placed on the upper limbs and the ice axe in three-dimensional space and real time at a frequency of 100 Hz (see Figure 5). The differences in amplitude between the elbow and wrist joints and the wrist and hand joints were calculated for the three phases of the ice axe strike: the swing, the strike and pulling out the axe. Strike speed and precision were used to evaluate performance; the calculation of the moment of inertia was used to assess the control of the movement.

43 Two types of experiential data were collected: audiovisual recording data during strikes and verbalization data during self-confrontation interviews. The interviews were conducted at the end of the protocol. The climber was confronted with the audiovisual recording of his activity and was invited by the researcher to tell, show, comment and mimic the meaningful elements for him as he interacted with the axes (Theureau, 2004, 2006, 2009 *op. cit.*). These interviews were aimed at collecting information on each climber's actions, perceptions and concerns during the strike (description of the variances or invariances of movement; description of the ease or difficulty in being precise; description of difficulties in gripping; description of the sensations of percussion and speed; description of the sensation of weight distribution) (Pouponneau, 2015 *op. cit.*). We then identified the typical concerns (i.e., grouping concerns by "family resemblance" according to Rosch; 1973) about each ice axe, then assessed the dynamics of these concerns during the three phases of the strike.

44 Third, the data were articulated with a balance between the kinematic and experiential data, which were processed independently. During data collection, neither type of data was considered more important than the other in selecting the dependent variables and analyzing the results. We thus were able to examine the convergence/divergence of the two types of data for the purpose of design assistance.

3.3.3. Summary of results: The effect of the type of ice axe on the climbers' experience (actions, perceptions and concerns) and kinematics

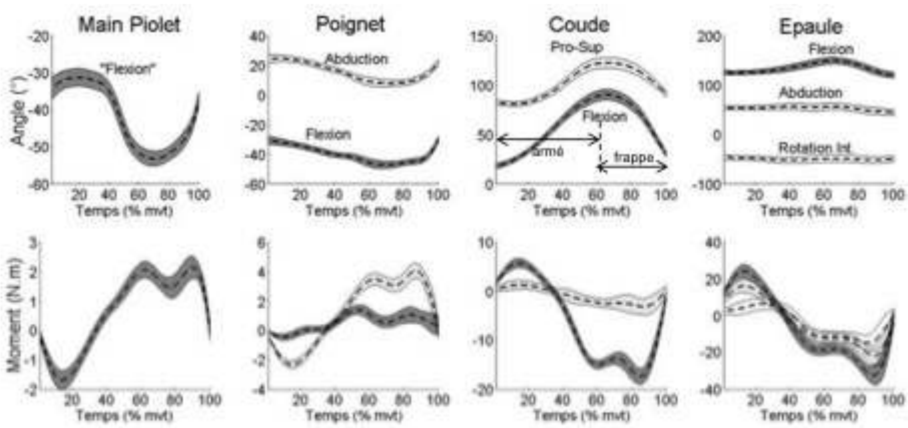
45 The results of the experiential data (actions and perceptions) regarding the criteria of expert striking, strike precision, axe grip, striking speed, pick penetration and weight distribution overall converged with those of the kinematic data (joint angle and moment of inertia) (Table 3 and Figure 6). The experiential data also made it possible to identify two typical concerns during the strikes: one related to energy saving and one to precision. In the phase of anchoring and then pulling out the axe, the climbers' first typical concern was to optimize energy for carrying out the strike: “In fact, what I'm looking for, I think, from the start is how I'm going to climb without wasting energy” (Climber 4, icefall axe). In this example, Climber 4 was trying to “not break the material and save energy so that you can climb for a long time without fatigue.” The second typical concern arose in the swing and striking phase. This was closely related to the first and concerned the precision and control of the strike. The strike was perceived as controlled at the wrist and seemed to be a very precise movement: “There's a rotation I don't know how ... It's not the shoulder that's moving backward” (Climber 7, dry-tooling axe).

46 This typical concern related to accuracy seemed to be confirmed by the kinematic data, since the greatest angular amplitudes were observed at the elbow and wrist (from 30° to 40°) rather than the shoulder (20°), suggesting that the ice axe strike is more a precision movement, or even a “throwing” move, than a hammer-type strike (Robert, Rouard, & Seifert, 2013; Rouard *et al.*, 2016 *op. cit.*). The shoulder and elbow were relatively fixed and the strike was initiated at the wrist (see Figure 6). While striking accuracy was perceived as being controlled, a nearly zero moment of inertia for all joints indicated that accuracy was not achieved by controlled end-to-end movement, suggesting that axe striking is similar to a ballistic movement of “launching” a projectile (Robert *et al.*, 2013, *op. cit.*; Rouard *et al.*, 2016 *op. cit.*) (see Figure 6).

Table 3: Actions and perceptions of climbers for the three types of ice axe.
Tableau 3 : Actions et perceptions des grimpeurs pour les trois types de piolet lors de la frappe

		 Piolet de goulotte	 Piolet de cascade	 Piolet de dry-tooling
Actions et perceptions lors de la frappe	Mouvement de frappe	Parfois ressenti comme étant de type marteau. Sensation d'un alignement poignet bras épaule.	Sensation d'une frappe enroulée autour du poignet.	Sensation d'une frappe enroulée qui part du haut vers le bas.
	Précision de la frappe	Ressenti très positif Amélioration rapide	Ressenti positif	Ressenti négatif. Demande une certaine. Concentration et maîtrise technique.
	Préhension du piolet	Douleurs dans les doigts. Gâchette gênante. Bras aligné avec le manche.	Sensation d'une main relâchée.	Manque de contrôle du manche dans la main. Crispations.
	Vitesse de la frappe et Pénétration de la lame	Sensation d'une frappe rapide avec une vitesse constante et une très bonne pénétration.	Sensation d'une frappe rapide avec une vitesse constante et une lame qui rentre facilement.	Sensation d'une accélération en fin de frappe due à la répartition des masses.
	Répartition des masses du piolet	Sensation d'une répartition homogène.	Sensation d'une répartition vers la tête du piolet	Sensation d'une répartition prononcée vers la tête du piolet

Figure 6: Example of joint amplitudes (top) and moments of inertia (bottom) for a participant during a series of ten strikes with the icefall axe (adapted from Robert *et al.*, 2013, *op. cit.*).
Figure 6 : Exemple d'amplitudes articulaires (en haut) et moments d'inertie (en bas) pour un participant lors d'une série de 10 frappes avec le piolet de cascade (adapté de Robert et al., 2013, op. cit.)



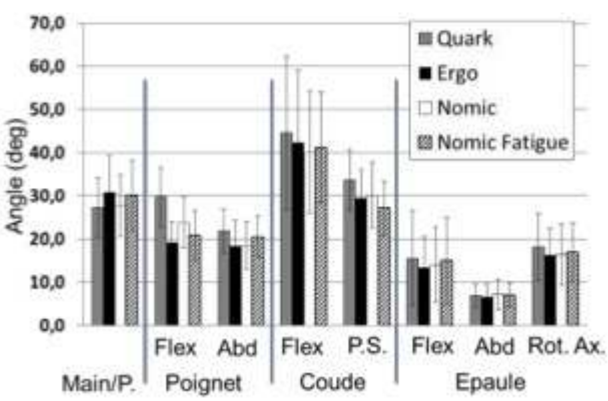
47 Each axe seemed to have specific dynamics (i.e., evolution during the three phases of the striking activity) for the typical concerns (Table 4). With the gully axe, the swing began with concerns for accuracy and economy. At the moment of the actual strike, only the concern related to energy saving was present and this lasted until the pick was pulled out. With the icefall axe, the concern for accuracy began during the swing and remained during the strike. With the dry-tooling axe, a concern about precision dominated the first two phases. Concern about energy economy was never experienced during the strike.

Table 4: Dynamics of climbers' concern-types for the three types of ice axe.
Tableau 4 : Dynamique des préoccupations-types des grimpeurs pour les trois types de piolet

			 Piolet de goulotte	 Piolet de cascade	 Piolet dry-tooling
		Préoccupations lors de l'activité « phase d'armé »	Cherche une position relâchée de la main sur le piolet. Cherche à réussir une frappe précise. Cherche à viser les trous.	Cherche une légère amplitude de mouvement. Cherche à se concentrer sur l'impact. Cherche à réussir une frappe précise	Cherche une amplitude de mouvement. Cherche à tendre le bras. Cherche à se concentrer sur l'impact. Cherche à réussir une frappe précise. Cherche à ne pas trop armer.
Déroulement de l'activité de frappe		Préoccupations lors de l'activité de frappe	Cherche l'efficience de la frappe. Cherche à ne pas frapper trop fort. Cherche un ancrage qui tient. Cherche à ne pas ancrer trop profondément. Cherche à s'économiser. Cherche à ancrer la lame suffisamment.	Cherche l'efficience de la frappe. Cherche à augmenter la précision de la frappe. Cherche à frapper perpendiculairement à la glace. Cherche à éviter les mouvements parasites. Cherche un ancrage qui tient. Cherche à ancrer la lame suffisamment Cherche à frapper très bas.	Cherche à réussir une frappe précise. Cherche le contrôle du piolet/limiter le rebond. Cherche le bon angle de pénétration de la lame dans la glace. Cherche à frapper sans dévier. Cherche à frapper droit. Cherche à éviter les mouvements parasites. Cherche à ancrer la lame suffisamment. Cherche à frapper très bas.
		Préoccupations lors de l'activité de désancrage	Cherche à limiter la profondeur de l'ancrage afin de désancrer facilement. Cherche à désancrer facilement. Cherche un désancrage économique.	Cherche un compromis entre ancrage suffisamment profond et désancrage facile. Cherche à désancrer facilement.	Cherche un compromis entre ancrage suffisamment profond et désancrage facile. Chercher le meilleur positionnement pour désancrer.

48 The kinematic data confirmed the differences between the axes. The joint amplitudes were slightly greater at the wrist and elbow for the gully axe, possibly explained by its grip and weight, 15% lighter than the other two axes (Robert *et al.*, 2013, *op. cit.*; Rouard *et al.*, 2016) (Figure 7). The gully axe also showed the highest impact speeds (8-10 $m.s^{-1}$ versus 7-9 $m.s^{-1}$ for the other two). However, experience and kinematics did not always converge. For example, the climbers perceived more precision with the gully axe (Table 3), whereas the kinematic data indicated the same precision with all three axes (<35 mm compared to the point before striking).

Figure 7: Joint amplitudes for hand-axe angle, wrist angle, elbow angle and shoulder angle with the three types of ice axe (gully: Quark; icefall: Nomic; dry-tooling: Ergo) in fresh and fatigued condition (Robert *et al.*, 2013 *op. cit.* ; Rouard *et al.*, 2016 *op. cit.*).
Figure 7 : Amplitudes articulaires pour l'angle main-piolet, poignet, coude et épaule avec les trois types de piolet (goulotte : Quark ; cascade : Nomic ; dry-tooling : Ergo) en condition fraiche et fatiguée (Robert et al., 2013 op. cit. ; Rouard et al., 2016 op. cit.)



49 The articulation of kinematic and experiential data showed overall convergence, which was used to identify the characteristics of expert ice axe striking. Nevertheless, discrepancies at the local level were observed (depending on the axe and strike phase), and these observations informed on the process of appropriation. In particular, the transparency/presence of the axes in relation to their economy-efficiency showed that the type of ice axe clearly brought out automatisms and subtle adjustments that were not meaningful for the climbers (such as differences in angular amplitude or striking speed). These biomechanical adjustments thus translated a process of appropriation in the climber-ice axe coupling, whereby the ice axe was incorporated as part of the climber's body, thus escaping pre-reflexive consciousness and making the articulation of the two types of data complementary. Indeed, the appropriation of a tool is dependent on time and how it is used, and the articulation of kinematic and experiential data over a (longer) time period would likely reveal more about the process of appropriation. Over a long period, transitions in the disturbance/ease or presence/transparency of the ice axes in relation to the convergence/divergence of the types of data would be identified. The convergence/divergence of behavioral and experiential data could also reveal changes in the appropriation of a tool over time and this might a help for the designer.

4. Discussion

50 These three studies in sports differed in their choices in methodological options, thus providing us with rich grounds for discussing articulatory methods within the course of action research program. Four points will be addressed: (1) the contributions of articulatory methodologies, (2) the limitations of articulatory methodologies within the CARP observatory, (3) design challenges, and (4) perspectives in the design of sports equipment and possible extensions to the analysis of work situations. These points will be considered through the three indicators that make up the framework for analysis using the articulatory approach: the nature of the data collected (experiential or behavioral data), the relationships between these data (subordination of one type to the other or equal status) and the conditions for data collection (in real situations or controlled environments).

4.1. Contributions of articulatory methodologies

51 This article has shown how activity in sports situations can be analyzed using three articulatory methodologies within the framework of the course of action research program. The differences are apparent in the conditions for collecting data (real situation or controlled environment), the nature of the data (experiential, biomechanical, kinematic), and the relationships between these data (primacy of intrinsic data or equal status).

52 This diversity of methodologies for observation is enriching with regard to the three functions: corroboration, elaboration or initiation (Greene *et al.*, 1989). Each function is linked to the data different types. Corroboration refers to the articulation of heterogeneous data to determine the convergence of the results, as this increases the validity of results from a single data source. For example, the "pad effect" at the imposed extreme speeds (slow and maximum) in the swimmers' interaction with the

MAD system was revealed by the converging analyses of the biomechanical and experiential data.

53 Elaboration is when the articulation of various types of data bring to light results that would never have been noticed without this process. In other words, the complementarity of articulated data can bring out more properties of an activity. For example, by articulating heterogeneous data from the ice climbers, we were able to characterize the process of appropriating ice axes through both verbalizable-conscious and behavioral-unconscious dimensions. Indeed, although the appropriation of sports equipment is a process often actualized by experiential data (Poizat *et al.*, 2010 *op. cit.*; Adé *et al.*, 2017 *op. cit.*), the articulation of these data with the kinematic data revealed dimensions of appropriation that were outside of awareness for the climbers, such as differences in angular amplitude or strike speeds.

54 Initiation characterizes the emergence of new research perspectives for articulating heterogeneous data. With the articulated approach, processing a single data source may point to new research questions that can only be answered by using other data sources. For example, the links for the trail runners between "the sloshing felt" (experiential data), "the sloshing measured" (kinematic data), and the physical characteristics of the trail opened up new areas of investigation, particularly concerning interpersonal differences in running patterns in connection with the perceived discomfort of the carrying and hydration system. New biomechanical parameters might be introduced to characterize, for example, the leg cycle (its length and duration) and stride (its amplitude and frequency).

4.2. Limitations of articulatory methodologies

55 Despite this methodological richness, limitations should be noted in relation with the theoretical hypotheses of CARP. The original authors of CARP argued for the circulation between first- and third-person data to analyze the actors' experience (Varela, & Shear, 1999; Theureau, 2004): "In brief, our stance in regards to first-person methodologies is this: don't leave home without it, but do not forget to bring along third-person accounts as well" (Varela, & Shear, 1999, p. 2). As CARP has been enriched over the years, the articulation methods have continued to show great diversity, which raises questions about two key hypotheses of the program: the hypothesis of enaction and the hypothesis of pre-reflexive consciousness, which has led to the primacy of the intrinsic (Seifert *et al.*, 2014 *op. cit.*; Mohamed, Favrod, Antonini Philippe, & Hauw, 2015; Adé, Ganière, & Louvet, 2018; Rochat *et al.*, 2018 *op. cit.*; Vors *et al.*, 2018 *op. cit.*; Vors *et al.*, 2019 *op. cit.*).

56 The first limitation is related to the primacy accorded to experiential data over other data sources. In CARP, the generative methodology coming from neurophenomenology (Lutz, 2002; Varela, 1996) and cardiophenomenology (Depraz *et al.*, 2017) is the most commonly used. It starts from first-person data to identify and sample the elements that might be relevant to study in the third person, as we saw in the study on trail runners. Yet, certain studies (e.g., Seifert *et al.*, 2017) have shown that the reverse order can be interesting, starting from a wide sample with third-person data and then quickly discerning (using methodological tools) a phenomenon that can be more richly explored with first-person data. One possible limitation is that the isolated phenomenon is not accessible to the actor's pre-reflexive consciousness. This was the

case for the climbers, who had no first-person perception of the differences in segmental angles or the moments of phase and antiphase in their coordination. In any case, as part of an articulatory approach, we contend that all heterogeneous data are important but that first-person data must be omnipresent within this heterogeneity.

57 The relationships to be established between first- and third-person data are not specified by CARP, the course of in-formation being based on "the data from pre-reflexive consciousness, external observation of the body, the actor's situation and culture, and the external observational data on the actor's behavior that may not have given rise to experience for the actor [...] while being nevertheless relevant for the actor's internal organization at all times" (Theureau, 2006, p. 50). However, it is difficult to identify the third-person elements that are "relevant for the actor's internal organization at all times" (Theureau, 2006, p. 50). Also, how is the dissonance between first- and third-person data when the third-person data are outside the actor's awareness or are not part of his or her internal organization at the moment of activity?

58 It is difficult to respond to this question precisely because no methodological path has been specified by CARP (Theureau, 2006). In addition, the limited amount of research including the theoretical object of the course of in-formation (e.g., Saury, Nordez & Sève, 2010; R'kiouak, Saury, Durand & Bourbousson, 2016, 2018; Petiot, 2019) makes any critical analysis unlikely to lead to serious methodological proposals. However, a promising avenue lies in the use of longitudinal studies that include the collection of first- and third-person data. A recent example of this longitudinal design was a ten-session learning protocol where novice climbers had the task of climbing an indoor climbing wall as smoothly as possible (Rochat *et al.*, 2020, *op. cit.*). Climbing fluency was measured by behavioral indicators and characterized by the learner's lived experience in terms of actions, perceptions, and concerns. One of the salient findings from the analysis and articulation of these two types of data was that the perceived fluidity could diverge from the measured fluidity. More specifically, as learning progressed, the climbers' perceptions of their fluidity became more refined, thus making them sensitive to disturbances that had not been salient during the first training sessions. This resulted in particular in discrepancies between perceived fluidity (e.g., climbers felt disturbances in their fluidity because they tuned in to very fine details of their bodily experiences, such as the feeling of jerkiness in hand movements) and measured fluidity, which reflected high climbing fluidity. It therefore seems that the longitudinal monitoring of changes in first- and third-person indicators can provide additional elements for analysis, showing how behavioral and experiential indicators can enrich each other.

59 The second limitation arising from the methodological diversity of the observatory concerns the environment chosen for analyzing activity and collecting research data. Technological constraints due to certain types of third-person data collection can lead to the construction of an "artificial" or "simulated" environment close to the ecological situation. This was the case, for example, of the study on climbers, where it was not possible to produce quality kinetic data in real icefall conditions with a system of eight optoelectronic cameras (VICON) recording in real time the positions of 19 reflective markers. Also, the task of striking a vertical target was not transferable to the ecological context of dry-tooling, where the climbing routes consist mainly of overhangs, and this raised questions about the generalization of the results. Indeed, one of the fundamental CARP assumptions, drawn from the enaction paradigm, is the

circular co-definition between the actor and the environment (Varela, 1989; Theureau, 2015). This coupling gives a central place to the environment in which the action takes place. However, the conditions for collecting third-person data (e.g., kinetic data) are not necessarily compatible with the ecological environment and therefore environments that we call "controlled" are created. The researchers thus must choose: should they keep the real situation but deprive themselves of certain third-person data accessible via methods and research tools requiring experimental conditions, or should they accept these constraints and free themselves from the in situ dimension to find compromises in the design and reconstruction of controlled environments? As part of an articulatory approach, this points to questions about how to define the minimal conditions that need to be respected in order to preserve ecological dimensions for collecting heterogeneous and meaningful data about the activity. The minimal ecological condition for data collection seems to be that the activity takes place either in its real context (like swimming) or in a context controlled by the researcher but in which the actor is encouraged to produce behaviors typical of the targeted activity. The circuit proposed in the trail study thus placed the runners in a situation of adapting their runs to the typical terrains encountered in trail races. In the climbing study, the climber faithfully reproduced the posture for using an ice axe by being suspended from an ice axe held by the non-preferential hand and carrying out the strike with the preferential hand. However, although we consider them acceptable, controlled data collection environments can never replace the real situation. As in the trail study, although the duration of the activity in a controlled environment remains out of step with real race situations, the duration of real race situations is often incompatible with the collection of research data. In such cases, it is the variety of the heterogeneous data that is likely to come to the researchers' aid, as was the case in the trail study, which drew on a history of race experiences reported by trail runners on dedicated forums.

4.3. Design issues

60 The contributions and limitations of articulatory methodologies in the field of sports expertise have direct relationships with the challenges of designing sports equipment. Asking questions about design suggests that new priorities might come to the fore: experiential data, behavioral data, their articulation, and the temporal dimension of design.

61 Experiential data provide inductive access to appropriation and usability in action, data that are not provided by the designer's predefined criteria. Thus, these data offer the researcher and the designer the possibility of "literalizing the empirical" (Theureau, 2006) by translating the cognitive, perceptual and affective processes at work in the interaction with the material artifact. This added value has already been demonstrated outside the sports field. This is the case, for example, in studies evaluating new communication technologies targeting design aids (Cahour *et al.*, 2007). Other avenues are also sometimes used, such as inviting practitioners of different levels and environments of practice to test the prototypes of products. Designers can include interview phases in their protocols when athletes test new equipment to determine how it is experienced. This active participation of users based on their experience makes it possible to propose and test alternative ideas in R&D departments. Necessary modifications to the prototype can be made before it goes into production. This amounts to seeing practitioners not simply as target audiences for brand marketing

strategies, but rather as part of the design process, co-designing material that corresponds to their needs and practice. These points about experience are in line with the "activity-centered" approach presented by Poizat, Haradji and Seifert (2011) as part of a process of designing sports equipment. The approach revealed that activity analysis opens up possibilities for fruitful innovations with regard to the technological expectations of designers. Activity analysis also makes it possible to reveal uses not anticipated by the designers. Finally, activity analysis is based on the coordination between designer, user and ergonomist at the various stages of the design process. In addition to activity analysis, the added value of our approach to design issues resides in the articulation of experiential data with third-person data.

62 Third-person data remains of great interest for design, however, because it provides access to the unconscious dimensions of the instrumented activity of sports experts. Indeed, expert sports activity grows out of appropriation processes in that expertise is built when material objects become transparent and ultimately escape the athletes' awareness. This occurred in the study of the climbers when the third-person data provided information about automatic actions and subtle adjustments that were not significant for them (like differences in angular amplitude or differences in striking speed). In general, the process of appropriating a tool is dependent on time and usage, and articulatory methodologies can be used over different time periods to reveal the process (discomfort/ease, presence/transparency of sports equipment).

63 Thus, articulatory methodologies seem particularly heuristic for design. The interest lies in the convergence/divergence relationships between the data. Convergence reinforces the results, similar to the triangulation process of other methodologies (e.g., Mathison, 1988; Johnson & Onwuegbuzie, 2004). Yet, divergence is also important as it may enrich understanding: it often signals a need to take a step back from the findings and can even lead to modifying the research object. These two effects of articulatory methods aid design by revealing characteristics of the activity that emerge only from heterogeneous data (e.g., Volkoff, 2005). For example, the study of swimmers using the MAD system helped the designer to see the need to modify the system's "pad effect" and particularly to change the inter-pad distances during extreme speeds so that swimmers could produce stroke lengths that felt close to those in in ecological swimming situations. Thus, it may be important to sensitize designers to the articulation of heterogeneous data so that they can avoid the potential sources of error that generate biased interpretations of data.

64 Last, the ergonomics of design may impose temporalities that are not always compatible with research. For example, the first-person analyses used in CARP are cumbersome because conducting the interviews, transcribing them, and reconstructing the courses of experience all take a lot of time. This limits the number of participants and the periods of activity that can be studied. To our knowledge, only five participants have been studied simultaneously in sports studies (e.g., Bourbousson, Poizat, Saury & Sève, 2008; Bourbousson *et al.*, 2011a; 2011b). This time-consuming dimension of CARP therefore sometimes requires "methodological arrangements." For example, time can be saved during data processing by focusing on generic categories of activity related to the usability and appropriation of sports equipment, without analyzing the hexadic sign and its concatenation. Thus, most studies in the field of sports expertise have focused on actions, perceptions and concerns, like the three studies presented in this article. Such methodological adaptations in processing first-person data are necessary

to respond to design challenges with short time frames and a large number of participants. This should encourage researchers to develop articulatory methodologies offering conditions for the collection and analysis of heterogeneous data that are rapid, reliable, extensive and usable by designers for transformative purposes.

4.4. Perspectives in design: possible extensions to the analysis of work situations

65 We have discussed the contributions and limitations of articulatory methods to aid the design of equipment in the field of sports. These articulatory methods that cross data on "lived activity" and "measured activity" seem heuristic for: (1) better understanding human activity and its complex organization (comprehensive aim), (2) favoring the design of activity aids (instruments, technologies, devices) (technological aim), and (3) encouraging the development of new design criteria (e.g., appropriation) or enrich existing criteria (e.g., usability). These methodologies may thus be usefully extended to fields other than sport. Recent work has indeed called for an articulatory methodology in the field of education (Adé *et al.*, 2018; Ganière, Adé & Louvet, 2020). In the context of physical education (PE), work has focused on the activity of students in refereeing situations in order to offer teachers avenues to help facilitate students' engagement in a social role often perceived as unattractive (ibid.). In real classroom situations, motivational data collected from questionnaires on the self-determined dimensions of student motivation (Deci, & Ryan, 2002) were combined with data on students' lived experience as referees. As for the three studies presented here, the results on student refereeing revealed the richness and usefulness of articulating heterogeneous data (in this case, data on the students' state based on criteria predefined with first-person experiential data) for transformative purposes. From a motivational perspective, the results pointed to the students' need for belonging in the refereeing situations and their activities to seek help from peers in assuming this role. All in all, refereeing activity in PE lessons emerged as a collective activity from which teachers can design more stimulating learning environments for referees (e.g., passing from an individual refereeing situation to shared refereeing).

66 More generally, this approach might be extended to analyze all work situations. Mouchet (2018) has certainly made the most progress in this direction, although he has partially distinguished his work from CARP's theoretical and methodological framework. Mouchet developed a "techno-psychophenomenological" approach to explore the potential of combining first-person data (experiential data) with third-person data that focus on the observable behaviors inherent to the actor's experience. Although sports were not his field of interest, he had a similar interest in complex and/or urgent situations and thus sought to characterize the decision-making activity of emergency physicians. Thus, for the conditions for data collection, the real situation of "medical emergency phone centers" was systematized. For the type of data, data on experience as a "reflective act" were mobilized by explicitation interviews (Vermersch, 2012), and the third-person data came from sociotechnical analyses (such as the spatial organization of the center) and the content of the recorded telephone calls. Last, in the articulation of the data, experiential data were most important. Three points therefore fundamentally distinguish the studies from CARP and Mouchet's work. The first is Mouchet's systematic study in real situations. The second is the nature of the data, particularly the level of lived experience. The third is the articulatory mode, which

subordinates third-person data to experiential data. Yet despite these differences, Mouchet's articulatory approach has delivered fruitful results in helping to design training devices for doctors in telemedicine and thus demonstrates its full potential for design. For this reason, we contend that articulatory methodologies can and should be extended to all work situations having a family resemblance to instrumented sports situations, with human activity, individual or collective, at the center of the analysis. For example, the work activity of firefighters, checkout agents or agricultural or construction workers seems likely to benefit from analyses of articulated heterogeneous data (including experiential and behavioral data), and these avenues of research would provide a deeper and richer understanding of these activities.

Conclusion

67 To achieve a deeper understanding of expertise in sport, recent studies carried out within the framework of the course-of-action research program have used what we call articulatory methodologies. The results have demonstrated the relevance of this approach for the epistemic and transformative design of sports equipment. We have pointed out the advantages, limitations and potentials, but we insist here on the need for an epistemological convergence of the various theoretical frameworks used to collect and process heterogeneous data. We have also focused here on the nature of the data and the ways to articulate them, but this should not be taken to mean that CARP does not have other methodological advances to offer. For example, other studies have concentrated on the dynamics of activity, successfully borrowing modeling tools from other scientific approaches (e.g., theory of dynamic systems) in order to explore these dynamics (e.g., Jourand, Adé, Sève, Komar, & Thouvarecq, 2017).

BIBLIOGRAPHY

Adé, D., Ganière, C., & Louvet, B. (2018). The role of the referee in physical education lessons : Student experience and motivation. Physical Education and Sport Pedagogy, 23(4), 418-430. https://doi.org/10.1080/17408989.2018.1455818

Adé, D., Seifert, L., Gal-Petitfaux, N., & Poizat, G. (2017). Artefacts and expertise in sport: an empirical study of ice climbing. International Journal of Sport Psychology, 48(1), 82-98.

Abernethy, B., Poolton, J. M., Masters, R. S. W., & Patil, N. G. (2008). Implications of an expertise model for surgical skills training. ANZ Journal of Surgery, 78, 1092-1095. https://doi.org/10.1111/j.1445-2197.2008.04756

Berteloot, A. (2008). La perception de l'effort chez des coureurs de demi-fond en compétition. Mémoire de Master. Université Rennes II.

Bland, M., & Altman, D. (1996). Measurement error and correlation coefficients. British Medical Journal, 313, 41-42.

Boff, K. R. (2006). Revolutions and shifting paradigms in human factors and ergonomics. Applied Ergonomics, 37(4), 391-399.

Bourbousson, J., & Fortes, M. (2012). Anthropologie cognitive et théorie des systèmes dynamiques : quelles articulations possibles dans l'analyse de l'activité collective ? In M. Quidu (éd.). Les Sciences du sport en mouvement. 171-185. Paris : L'Harmattan.

Bourbousson, J., Poizat, G., Saury, J., & Sève, C. (2008). Caractérisation des modes de coordination interpersonnelle au sein d'une équipe de basket-ball. Activités, 5(1), 21-39.

Bourbousson, J., Poizat, G., Saury, J., & Sève, C. (2011a). Cognition collective : Partage de préoccupations entre les joueurs d'une équipe de basket-ball au cours d'un match. Le travail humain, 74(1), 59-90.

Bourbousson, J., Poizat, G., Saury, J., & Sève, C. (2011b). Description of dynamic shared knowledge : An exploratory study during a competitive team sports interaction. Ergonomics, 54(2), 120-138.

Button, C., Seifert, L., Araujo, D., Chow, JY., & Davids, K. (2020). Dynamics of Skill Acquisition. Human Kinetics Publisher, 2nd edition.

Cahour, B., Brassac, C., Vermersch, P., Bouraouis, J., Pachoud, B. & Salembier, P. (2007). Étude de l'expérience du sujet pour l'évaluation de nouvelles technologies : l'exemple d'une communication médiée. Revue d'anthropologie des connaissances, 1(1), 85-120. https://doi.org/10.3917/rac.001.0085

Chollet, D., Madani, M., & Micaleff, J.P. (1992). Effects of two types of biomechanical biofeedback on crawl performance. In D. MacLaren, T. Reilly, & A. Less (Eds.). Swimming Science VI (57-62). London : E & FN Spon.

Davids, K., Hristovski, R., Araújo, D., Balague Serre, N., Button, C., & Passos, P. (2014). Complex systems in sport. London, UK : Routledge, Taylor & Francis Group.

Deci, E., & Ryan, R. (2002). Handbook of self-determination research. Rochester, NY : University of Rochester Press.

Depraz, N., Gyemant, T., & Desmidt, S. (2017). A first-person analysis using third-person data as a generative method: A case study of surprise in depression. Constructivst Foundations, 12(2), 190-203.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological Review, 100(3), 363-406.

Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: Evidence of Maximal Adaptation to Task Constraints. Annual Review of Psychology, 47, 273-305. https://doi.org/10.1146/annurev.psych.47.1.273.

Gal-Petitfaux, N., Adé, D., Poizat, G., & Seifert, L. (2013). L'intégration de données biomécaniques et d'expérience pour comprendre l'activité de nageurs élites et concevoir un dispositif d'évaluation. Le Travail Humain, 76, 257-282.

Ganière, C., Adé, D., & Louvet, B. (2020). Arbitrer en EPS : Une expérience de responsabilisation. eJRIEPS, spécial 3. https://doi.org/10.4000/ejrieps.4491

Garrett, J. J. (2010). Elements of User Experience, The: User-Centered Design for the Web and Beyond. London : Pearson Education.

Gesbert, V., Durny, A., & Hauw, D., 2017. How Do Soccer Players Adjust Their Activity in Team Coordination ? An Enactive Phenomenological Analysis. Frontiers in Psychology, 8(854).

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a Conceptual Framework for Mixed-Method Evaluation Designs. Educational Evaluation and Policy Analysis, 11(3), 255-274. https://doi.org/10.3102/01623737011003255

Hauw, D. (2018). Énaction et intervention en psychologie du sport chez les sportifs élites et en formation. Revue canadienne des sciences du comportement, 50(1), 54-64.

Hauw, D., Rochat, N., Gesbert, V., Astolfi, T., Antonini, Philippe, R., & Mariani, B. (2016). Putting together first- and third-person approaches for sport activity analysis : The case of ultra-trail runners' performance analysis. In P. Salmon, A.C. Macquet (Eds.), Advances in Human Factors in Sports and Outdoor Recreation (pp. 49-59). Switzerland : Springer International Publishing Switzerland.

Hassenzahl, M., Law, E. L. C., & Hvannberg, E. T. (2006). User experience-towards a unified view. UX WS NordiCHI, 6, 1-3.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research : A Research Paradigm Whose Time Has Come. Educational Researcher, 33(7), 14-26. https://doi.org/10.3102/0013189X033007014

Jourand, C., Adé, A., Sève, C., Komar, J., & Thouvarecq, R. (2017). Dynamics of student interactions: an empirical study of orienteering lessons in physical education. Physical Education and Sport Pedagogy, 23(2), 134-149. https://doi.org/10.1080/17408989.2017.1342790

Lenay, C. (2006). Énaction, externalisme et suppléance perceptive. Intellectica, 43, 27-52.

Lutz, A. (2002). Toward a neurophenomenology as an account of generative passages: A first empirical case study. Phenomenology and the Cognitive Sciences, 1(2), 133-167. https://doi.org/10.1023/A:1020320221083

Mathison, S. (1988). Why Triangulate? Educational Researcher, 17(2), 13-17. https://doi.org/10.3102/0013189X017002013

Mohamed, S., Favrod, V., Antonini Philippe, R., & Hauw, D. (2015). The Situated Management of Safety during Risky Sport : Learning from Skydivers' Courses of Experience. Journal of Sports Science and Medicine, 14(2), 340-346.

Mouchet, A. (2018). L'expérience subjective en recherche et en formation. Presses universitaires du Septentrion.

Nielsen, J. (1993). Usability Engineering. Boston : Academic Press.

Norman, D., & Draper, S. W. (1986). User centered system design. New-York : Hillsdale.

Petiot, O. (2019). Favoriser l'engagement des élèves dans les activités d'apprentissage en EPS dès le début de l'année scolaire : Modalités d'intervention d'enseignants d'EPS experts, dispositions à agir sous-jacentes, et effets sur l'engagement des élèves [PhD Thesis]. Nantes.

Poizat, G. (2006), Analyse en ergonomie cognitive de l'activité collective en tennis de table. Contribution à la connaissance des interactions humaines. Thèse de Doctorat non publiée, Université de Rouen, Rouen.

Poizat, G., Adé, D., Seifert, L., Toussaint, H., & Gal-Petitfaux, N. (2010). Evaluation of the measuring active drag system usability: An important step for its integration into training sessions. International Journal of Performance Analysis of Sport, 10, 170-186.

Poizat, G., Haradji, Y., & Seifert, L. (2011). Concevoir du matériel sportif à partir d'une approche centrée sur l'activité : Une alternative en ergonomie du sport. STAPS, 4, 71-83.

Pouponneau, C. (2015). Analyse de l'activité de glaciéristes dans une perspective de conception de matériel de progression pour l'escalade et la montagne : contribution à l'élaboration d'un programme de recherche technologique en ergonomie du sport. Thèse de doctorat non publiée, Université de Bourgogne - Franche-Comté, Dijon, France.

Pouponneau, C., Poizat, G., Gal-Petitfaux, N., & Adé, D. (2011, October). Analyse de l'activité de glaciéristes débutants utilisant différents piolets : une étude de cas exploratoire. Paper presented at the 14th International meeting of A.C.A.P.S., Rennes.

Preece, J. R., & Rogers, Y. (2007). Interaction Design: Beyond Human-Computer Interaction. Crawfordsville : John Wiley and Sons.

Quidu, M., & Favier-Ambrosini, B. (2014). L'articulation des données en première et troisième personnes. Intellectica, 2(62), 7-34.

R'Kiouak, M., Saury, J., Durand, M., & Bourbousson, J. (2016). Joint Action of a Pair of Rowers in a Race: Shared Experiences of Effectiveness Are Shaped by Interpersonal Mechanical States. Frontiers in Psychology, 7. https://doi.org/10.3389/fpsyg.2016.00720

R'kiouak, M., Saury, J., Durand, M., & Bourbousson, J. (2018). Joint action in an elite rowing pair crew after intensive team training: The reinforcement of extra-personal processes. Human movement science, 57, 303-313.

Récopé, M., Fache, H., Beaujouan, J., Coutarel, F., & Rix-Lièvre, G. (2019). A study of the individual activity of professional volleyball players: Situation assessment and sensemaking under time pressure. Applied Ergonomics, 80, 226-237. https://doi.org/10.1016/j.apergo.2018.07.003

Robert, T., Rouard, A., & Seifert, L. (2013). Biomechanical analysis of the strike motion in ice-climbing activity. Computer methods in biomechanics and biomedical engineering, 16(sup1), 90-92.

Rochat, N., Hacques, G., Ganière, C., Seifert, L., Hauw, D., Iodice, P., & Adé, D. (2020). Dynamics of Experience in a Learning Protocol: A Case Study in Climbing. Front. Psychol. 11 (249). https://doi.org/10.3389/fpsyg.2020.00249

Rochat, N., Hauw, D., & Seifert, L. (2018). Enactments and the design of trail running equipment: An example of carrying systems. Applied Ergonomics. https://doi.org/10.1016/j.apergo.2018.07.002

Rochat N., Seifert L., Guignard B., & Hauw D. (2019). An enactive approach to appropriation in the instrumented activity of trail running. Cognitive processing, 20(4), 459-477.

Rosch, E. H. (1973). On the internal structure of perceptual and semantic categories. In T. E. Moore (Ed.), Cognitive development and the acquisition of languagep (pp. 111-144). Academic Press.

Rouard A., Robert T., & Seifert L. (2016). Biomechanics of ice tool swinging movement. In L. Seifert, P. Wolf, & A. Schweizer (Eds.), Science of Climbing and Mountaineering (pp. 210-223). London, UK : Routledge, Taylor & Francis.

Saury, J., Nordez, A., & Sève, C. (2010). Coordination interindividuelle et performance en aviron : apports d'une analyse conjointe du cours d'expérience des rameurs et de paramètres mécaniques. Activités, 7, 2-27. https://doi.org/10.4000/activites.2369

Seifert, L., Button, C., & Davids, K. (2013). Key properties of expert movement systems in sport: an ecological dynamics perspective. Sports Medicine, 43(3), 167-12578. https://doi.org/10.1007/s40279-012-0011-z.

Seifert, L., Lardy, J., Bourbousson, J., Adé, D., Nordez, A., Thouvarecq, R., & Saury, J. (2017). Interpersonal Coordination and Individual Organization Combined with Shared Phenomenological Experience in Rowing Performance: Two Case Studies. Front. Psychol. 8(75). https://doi.org/10.3389/fpsyg.2017.00075

Seifert, L., Wattebled, L., Herault, R., Poizat, G., Adé, D., Gal-Petitfaux, N., & Davids, K. (2014). Neurobiological degeneracy and affordance perception support functional intra-individual variability of inter-limb coordination during ice climbing. PloS one, 9(2). https://doi.org/10.1371/journal.pone.0089865

Sève, C., Nordez, A., Poizat, G., & Saury, J. (2013). Performance analysis in sport: Contributions from a joint analysis of athletes' experience and biomechanical indicators. Scandinavian journal of medicine & science in sports, 23(5), 576-584.

Theureau, J. (2004). Le cours d'action. Méthode élémentaire. Toulouse : Octarès.

Theureau, J. (2006). Le cours d'action. Méthode développée. Toulouse : Octarès.

Theureau, J. (2009). Le cours d'action. Méthode réfléchie. Toulouse : Octarès.

Theureau, J. (2011). Appropriations 1, 2 & 3. Communication aux Journées ErgoIDF : Appropriation et ergonomie (Paris, France, 16 June).

Theureau, J. (2015). Le cours d'action. L'énaction et l'expérience. Toulouse : Octarès.

Theureau, J., Filippi, G., Saliou, G., & Vermersch, P. (2001). Development of a methodology for analysing the dynamic collective organisation of the reactor operator's and supervisor's courses of experience while controlling a nuclear reactor in accidental situations in full scope simulated control rooms. In CSAPC'01 Proceedings, 23-26 septembre, Munich.

Toussaint, H.M., & Truijens, M. (2005). Biomechanical aspects of peak performance in human swimming. Animal Biology, 55, 17-40.

Toussaint, H.M., van der Meer, S., de Niet, M., & Truijens, M. (2006). Propelling efficiency in sprint front crawl swimming. Portuguese Journal of Sports Sciences, 6, 279-282.

Toussaint, H.M., & Vervoorn, K. (1990). Effects of specific high resistance training in the water on competitive swimmers. International Journal of Sports Medicine, 11, 228-233.

Varela, F.J. (1989). Autonomie et connaissance. Essai sur le vivant. Paris : Seuil.

Varela F. J. (1996). Neurophenomenology: A Methodological Remedy for the Hard Problem, Journal of Consciousness Studies, 3(4), 330-350.

Varela, F., & Shear, J. (1999). First-person methodologies : What, why, how? Journal of Consciousness Studies, 6(2-3), 1-14.

Varela, F.J., Thompson, E., & Rosch, E. (1993). L'inscription corporelle de l'esprit. Paris : Seuil.

Vermesch, P. (2012). Explicitation et phénoménologie. Paris : PUF.

Villame, T. (2004). Conception de systèmes d'assistance au conducteur : comment prendre en compte le caractère, dynamique et situé de la conduite automobile ? Cognition située et conception de systèmes d'assistance au conducteur. Activités, 1, 146-169.

Volkoff, S. (2005). L'ergonomie et les chiffres de la santé au travail : Ressources, tensions et pièges. Collection Travail et Activité humaine. Toulouse : Octarès.

Vors, O., Cury, F., Marqueste, T., & Mascret, N. (2019). Enactive Phenomenological Approach to the Trier Social Stress Test : A mixed methods point of view. JOVE - Journal Of Visualized Experiments, 143, e58805. https://doi.org/10.3791/58805

Vors, O., Marqueste, T., & Mascret, N. (2018). The Trier Social Stress Test and the Trier Social Stress Test for groups: Qualitative investigations. PLOS ONE, 13(4), e0195722. https://doi.org/10.1371/journal.pone.0195722

ABSTRACTS

This article examines the expansion of methodologies for articulating heterogeneous (experiential and behavioral) data within the course-of-action research program (Theureau, 2004, 2006, 2009, 2015). In the area of sports expertise, recent studies have articulated verbalizations based on conscious awareness and behavioral data from largely unconscious processes in order to shed light on expert instrumented activity. The methodological differences between these studies are highlighted, especially regarding the priority given to the types of data and the conditions under which these data were collected. Three studies are presented, covering trail running, swimming, and ice climbing, and each is distinct in its conditions for data collection and processing and its methodology for data articulation. We examine their advantages and limitations for aiding the design of sports equipment and question the observatory within the course-of-action research program. Essentially, the program's methodological advances raise questions about how sports equipment is designed, the athlete-researcher-designer relationship, and the heuristic scope for analyzing activity in work situations that share similarities with the instrumented activity of sports situations.

L'objectif de cet article est d'analyser et de discuter de l'évolution des méthodologies articulant des données hétérogènes (i.e., expérientielles et comportementales) qui se développent actuellement dans le cadre du programme de recherche du cours d'action (Theureau, 2004, 2006, 2009, 2015). Dans le domaine de l'expertise en sport, ont été récemment conduites des recherches qui ont articulé des données verbalisables-conscientisables et des données comportementales non conscientes afin de renseigner l'activité instrumentée experte. Il est constaté des différences méthodologiques entre ces études concernant le poids accordé et le degré d'équilibre entre ces données hétérogènes et des conditions de recueil et traitement de celles-ci. Trois études sont présentées en trail, en natation, et en cascade de glace, distinctes de par leur méthodologie articulatoire et leur condition de recueil et traitement des données, à partir desquelles sont envisagés les avantages et limites pour l'aide à la conception du matériel sportif et un questionnement sur l'observatoire du programme de recherche du cours d'action. Au total, cette évolution méthodologique dans ce programme de recherche invite à questionner les méthodes de conception du matériel sportif, les relations sportif – chercheur – concepteur et la portée heuristique pour l'analyse de l'activité en situation de travail possédant des similarités avec l'activité instrumentée dans les situations sportives.

INDEX

Mots-clés: activité sportive instrumentée, expertise, conception, données comportementales, données d'expérience
Keywords: instrumented sports activity, expertise, sports equipment design, behavioral data, experiential data

AUTHORS

DAVID ADÉ

Université de Rouen Normandie, CETAPS, Bd Siegfried, Mont-Saint-Aignan, 76821, France, david.ade@univ-rouen.fr

NATHALIE GAL-PETITFAUX

Université Clermont Auvergne, ACTé, Les Cézeaux, 3 rue de la Chebarde, Aubière, 63178, France, nathalie.gal-petitfaux@uca.fr

NADÈGE ROCHAT

Université Grenoble Alpes, CNRS, Grenoble INP, GIPSA-Lab, 38000 Grenoble, France, nadege.rochat@grenoble-inp.fr

LUDOVIC SEIFERT

Université de Rouen Normandie, CETAPS, Bd Siegfried, Mont-Saint-Aignan, 76821, France, ludovic.seifert@univ-rouen.fr

OLIVIER VORS

Aix Marseille Université, CNRS, ISM, Marseille, France ; SFERE-Provence, FED 4238, Marseille, France, 163 avenue de Luminy, Marseille cedex 09, 13288 France, olivier.vors@univ-amu.fr