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PREMIÈRE PARTIE

CARACTÉRISER LA NATURE DES ANCRAGES INFORMATIONNELS

ÉTUDE 1

JOINT ACTION OF A PAIR OF ROWERS IN A RACE: SHARED EXPERIENCES OF EFFECTIVENESS ARE SHAPED BY INTERPERSONAL MECHANICAL STATES

R'Kiouak, M., Saury, J., Durand, M. & Bourbousson, J.

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Joint Action of a Pair of Rowers in a Race: Shared Experiences of Effectiveness Are Shaped by Interpersonal Mechanical States

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The purpose of this study was to understand how a single pair of expert individual rowers experienced their crew functioning in natural conditions when asked to practice a joint movement for the first time. To fulfill this objective, we conducted a field study of interpersonal coordination that combined phenomenological and mechanical data from a coxless pair activity, to analyze the dynamics of the (inter)subjective experience compared with the dynamics of the team coordination. Using an enactivist approach to social couplings, these heterogeneous data were combined to explore the salience (and accuracy) of individuals' shared experiences of their joint action. First, we determined how each rower experienced the continuous crew functioning states (e.g., feelings of the boat's glide). Second, the phenomenological data helped us to build several categories of oar strokes (i.e., cycles), experienced by the rowers as either detrimentally or effectively performed strokes. Third, the mechanical signatures that correlated with each phenomenological category were tracked at various level of organization (i.e., individual-, interpersonal-, and boat-levels). The results indicated that (a) the two rowers did not pay attention to their joint action during most of the cycles, (b) some cycles were simultaneously lived as a salient, meaningful experience of either a detrimental ($n = 15$ cycles) or an effective ($n = 18$ cycles) joint action, and (c) the mechanical signatures diverged across the delineated phenomenological categories, suggesting that the way in which the cycles were experienced emerged from the variance in some mechanical parameters (i.e., differences in peak force level and mean force). Notably, the mechanical measures that helped to explain differences within the phenomenological categories were found at the interpersonal level of analysis, thus suggesting an intentional interpersonal mode of regulation of their joint action. This result is further challenged and discussed in light of extra-personal regulation processes that might concurrently explain why participants did not make an extensive salient experience of their joint action. We conclude that attempts to combine phenomenological and mechanical data should be pursued to continue the research on how individuals regulate the effectiveness of their joint actions' dynamics.

Keywords: mixed method, enaction, interpersonal coordination, extrapersonal coordination, rowing, course of action, subjectivity-based sampling method

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INTRODUCTION

Joint action is a ubiquitous phenomenon underlying most daily activities, especially when interpersonal sensorimotor coupling is involved. Joint action has been abundantly investigated in human movement science using kinematics descriptions (Schmidt and O'Brien, 1997; Romero et al., 2012), and to a lesser extent by describing the embodied perceptive (and/or subjective) activities implied in its active regulation (Laroche et al., 2014). In the mainstream research on joint action, most studies that have involved the participants' lived (i.e., subjective) experience of ongoing team coordination have been controlled by the experimental instructions given to the participants.

The first part of this stream of research has considered the role of the participant's lived concerns by focusing on the intentional features (i.e., the participant's explicit experience of regulating his behavior) underlying the regulatory mechanisms. Typically, pairs of participants were asked to coordinate their oscillating legs (alternately in phase and anti-phase patterns) and to actively/explicitly regulate the coordination so that the emergent states of synchrony/asynchrony perceived on the fly would remain stable overtime (Schmidt et al., 1990). This study has been compared to a companion one in which participants instead were asked to remain aware of their lived experience of comfort and to regulate their behavior accordingly. The comparison of both types of awareness showed that the degree of active perceptive regulation was a critical process that controlled the fluctuations and phase transitions within the emerging team coordination states. Such observations particularly illustrate how a change in the subjective regulation of the participants (i.e., being more or less active or/and explicit to them) might shape the biomechanical signatures of the ongoing joint action.

The second part of the research has focused on the unperceived aspects underpinning the dynamics of team coordination, which form the behavioral facet of the coordination that is meaningless to the participants. To illustrate, Schmidt and O'Brien (1997) asked participants, placed in pairs, to avoid synchronous oscillations while swinging a pendulum with their arms. They observed that the participants were able to prevent this coordination from occurring only in the absence of informational exchanges (i.e., not mutually visible). Otherwise, and despite the instruction of avoiding synchronization, a tendency to phase-lock emerged when the participants were informationally coupled (i.e., they were able to perceive each other's moves). Such study highlights how implicit features (i.e., an absence of awareness of the emerging team coordination states) shape the action and perception loop underlying joint action. In doing so, this study questions both the way in which actors might be aware of their ongoing interaction, and the way in which explicit/meaningful regulation is shaped by processes similar to unintentional/unperceived coordination.

While some researchers call for investigating the lived experience of the actors as an important part of the joint action process itself (De Jaegher and Di Paolo, 2007), very few studies have considered the awareness and the sense-making activity of the actors as a valuable topic for research (Gallagher, 2009; De Jaegher et al., 2010; Froese and Di Paolo, 2010). Yet, empirical evidence has shown that with increasing expertise, actors are more likely to use lived experience to actively regulate the dynamics of the joint action (Schiavio and Høffding, 2015). In this light, thanks to their study of team rowing coordination in a natural setting, Lund et al. (2012) suggested that participants learned to coordinate by gradually and systematically adjusting their shared experiences over time. As claimed by Heath et al. (2002), such an active regulation by actors in organizational settings is enable by a skillful use of their lived experience to monitor the ongoing team coordination of which they are part. However, very little evidence has been provided of the salience and accuracy of such an online awareness in either human movement science or sports science. Together, these elements demonstrate that the way joint movement is experienced remains a neglected topic within joint action research.

A recent study carried out on the sport field selected rowing as a setting to describe how athletes experienced their activity and the accuracy of their awareness (Millar et al., 2015). While the study investigated coordination phenomena only at an intrapersonal scale, it gave insights into the role of the online lived experience of actors in regulating their action and perception dynamics. In particular, the study suggested that with increased expertise, the rowers are more likely to be aware of the ongoing changes within the performance states (i.e., change in boat speed), even more than their coaches are from their external point of view. This study thus illustrates how expert performers might be able reliably to live and account for their dynamical individual activity. However, it is still unknown whether expert individual performers exhibit the same salient awareness of their activity when involved in a joint action task. In this light, investigations of phenomenological phenomena are still needed in the research on joint action processes. Quite novel in the field, the present study was exploratory and described the systematic lived experience of participants regarding their joint movement. The study was conducted in a natural setting of rowing. By combining phenomenological data with behavioral data (i.e., mechanical measures) and by using an original methodological design, we aimed to discuss the ways in which humans actively manage their emerging experience of the team coordination states.

The present study was designed with respect for an enactivist approach to social couplings (De Jaegher and Di Paolo, 2007; Laroche et al., 2014) to address the extent to which actors had shared meaningful lived experiences through the joint movement behavioral states. By combining a phenomenological description of their activity with a behavioral description, we aimed to explore the accuracy of such experiences.

The enactivist view to social couplings assumes that joint action processes should be investigated by reconstructing the way in which individuals live in their own worlds that are mutually coupled. Such a joint sense-making activity is assumed precarious in that individuals sense-making activities shape and are shaped by the fluctuating dynamics of the behavioral facet of the coupling to which they are contributing. An enactivist approach to the analysis of joint action thus aims to describe how the behavioral facet of the social coupling needs to complement the (inter)subjective facet in which it is embedded. This framework aims to contribute to a paradigm shift in cognitive science (Varela, 1979), as the researchers present a non-representational frameworks in social cognition science (e.g., Varela, 1979; Varela et al., 1991). Instead of rejecting the subjectivity of participants (i.e., as in some of the non-representationalist views of cognition), the enactivist approach conceives it as a main component in the active regulation of the situated embodied activity. Thus, following a careful phenomenological framework (e.g., Theureau, 2003), the enactivist approach considers the "own world" of humans as the product of (a) the nature of their sensory apparatus that is genetically inherited, (b) the history of the actor/environment coupling (e.g., recurrent patterns of perception and action built during individual development), and (c) the way in which individual experiences his/her coupling with the environment in the moment (Thompson, 2011). This last assumption makes the situated experience lived by each of the performers the *sine qua non* condition for describing how their behaviors are systematically arranged into dynamic patterns in their real-time activity.

The present field study of joint action in a rowing crew combined the data from two alternative research traditions within activity analysis: the dynamics of the lived experience and the dynamics of the behavior. These data have been combined with a view to explore how individual lived experiences are tightly nested in the active regulation of joint action between two elite performers who have not been trained to row together. To explore the behavioral facet in which lived experiences are dynamically anchored, our starting point was to determine how each rower experienced the continuous coordination states during their race. Such phenomenological data helped to build several samples of oar strokes, differentially experienced. Grounded on such a subjectivity-based sampling method (Lutz et al., 2002), we then scrutinized the behavioral facet of the strokes by characterizing the specific behavioral signatures underlying the identified lived experiences, as captured at various levels of analysis. The following research questions drove the present study: (a) to what extent do individual coxless pair rowers report salient, meaningful lived experiences of their joint action effectiveness? (b) To what extent are these experiences similar across rowers? (c) Are distinct shared lived experiences of joint action effectiveness associated with distinct mechanical signatures? Finally, (d) to what extent do shared lived experiences of joint action effectiveness capture behavioral instances of expert team coordination?

MATERIALS AND METHODS

Characteristics of the Setting under Study

The naturalistic conditions of rowing (i.e., on water) have been selected for investigating joint action and the related shared lived experiences of rowers. Team coordination has been shown to be one of the major performance factors in crews of two or more rowers (Wing and Woodburn, 1995; Hill, 2002; Smith and Draper, 2002; Baudouin and Hawkins, 2004). In such an interactive performance setting, rowers are mutually involved in a permanent real-time regulation of the emerging behavioral states of team coordination (Pinder et al., 2011). Much feedback is available for rowers during their race –they can feel their teammate's oar blade enter the water through the boat movement, the boat's roll, or their common propulsion, which makes this setting also particularly attractive for exploring the rowers' lived experience (Millar et al., 2013). This abundance of feedbacks is likely to produce a rich amount of sense-making activity, although it may make it complex. Moreover, the existing mechanical capture systems allow the collection of a large amount of behavioral data in natural settings (i.e., on the water) at different levels of the social system: individual level (e.g., forces, angles measures; Ishiko, 1971; Schneider et al., 1978; Kleshnev, 2011); interpersonal level (e.g., time gaps in the entry into water of the rowers' oar; Sève et al., 2013) and the boat's level (e.g., boat speed; Hill, 2002; Baudouin and Hawkins, 2004). Such a setting offers a rich opportunity to advance the research on team coordination in general and on multi-level approaches of joint action in particular (Cooke et al., 2013; Kozlowski et al., 2013; Humphrey and Aime, 2014; Bourbousson et al., 2015).

Participants and Procedure

A junior men's coxless pair aged 17 years with 10 years' experience in rowing participated in this study with the collaboration of their coach. The participants had no shared experience in rowing coxless pair together (i.e., this was their first season rowing together). The data collection occurred at the very first step of a 1-month crew-training period before the national championship in which the pair were to perform together. Both participants were current members of the French Rowing Academy (Nantes, France). The "stroke rower" is seated on the closest seat to the stern of the boat (i.e., he doesn't see his teammate; see **Figure 1**) and, as described in the rowing training theories (Lippens, 2005), he propels the boat and set the rhythm. The "bow rower" is seated on the first seat, near to the bow of the boat (i.e., he sees the back of his teammate; see **Figure 1**) and he is supposed to follow the movement of the stroke rower to coordinate with him. Participants were in the top 10 of their category in France. This study was performed in accordance with the Declaration of Helsinki and the APA ethics guideline. It was approved by a local Institutional Review Board of the university. The two rowers and their coaches were informed of the procedures and gave their consent.

The two coxless rowers conducted a 12-min race of sub-maximal on-water rowing at 18–19 strokes per min (spm), as intended for the analysis. Sub-maximal is considered to be at 70–75% of the participant's fastest speed, with a heart rate is below 145–156 beats per minute (bpm). This race thus account for the very first stage of team training, which was assumed to capture the initial learning processes of a newly formed crew composed of expert individual rowers.

Data Collection

Two distinct data sets were collected to account for the activity of the two rowers during the race. First, the phenomenological data were recovered through individual self-confrontation interviews (Theureau, 2003) with each rower. Second, the behavioral data

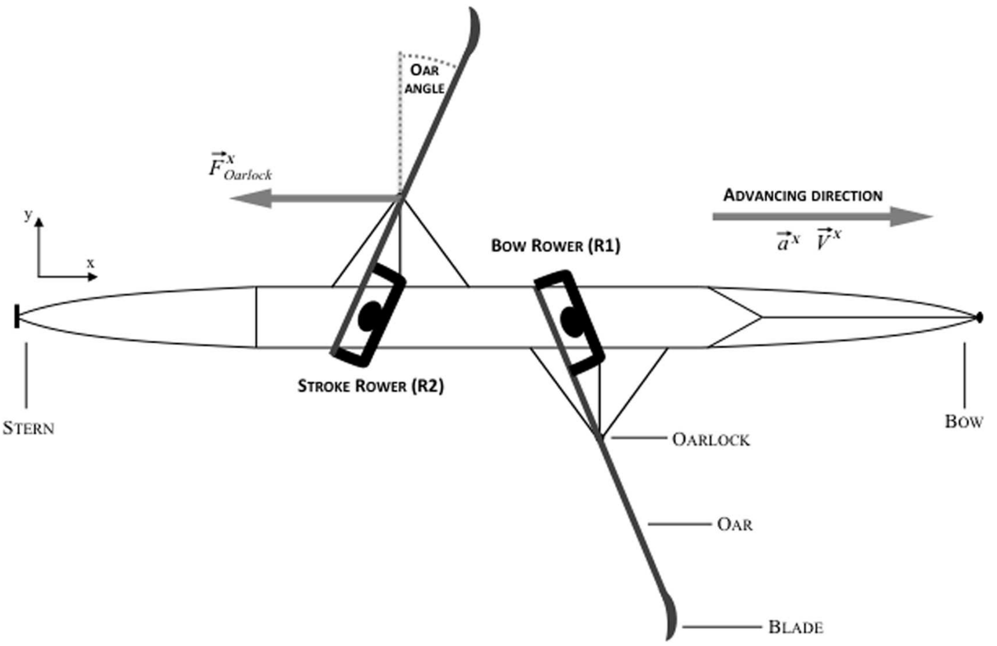

FIGURE 1 | Bird's-eye view of a coxless pair. The onboard measurement system (Powerline, Peach Innovation) records the components of the forces applied by the rowers to the oarlock along the *x*-axis (in the direction of the boat's movement), the acceleration, the speed of the boat, and the angle formed by the oar with the *y*-axis (perpendicular to the boat's movement).

were recovered using an automatic mechanical device during the race.

Phenomenological Data Collection

The actors' phenomenology was the starting point for the descriptions of the actor/environment coupling. This was consistent with the enactivist view to social couplings and the claim that human activity displays autonomous characteristics that are not reducible to behavioral descriptions (Varela et al., 1991). The enactivist approach therefore devotes special attention to pre-reflective self-conscious phenomena, that is, the implicit ways in which a given actor experiences his/her ongoing activity. To capture actors' phenomenology through their pre-reflective self-consciousness embedded in the unfolding activity (i.e., lived experience), our study included a methodology that used phenomenological forms of retrospective interviews. From this perspective, at each instant of the race under study, we used self-confrontation interview techniques to collect the phenomenological data that accounted for the pre-reflective self-consciousness of the participants. This was consistent with recent enactive studies in sports (Bourbousson et al., 2011, 2012; Poizat et al., 2012; Sève et al., 2013; Bourbousson et al., 2015; Araujo and Bourbousson, 2016).

To this end, each rower of the coxless pair was filmed individually during the race by two video cameras located in a second boat that followed the rowing boat. Each rower was equipped with a high-fidelity microphone. Together, the recordings allowed us to collect the rowers' behaviors and verbal communications. These behavioral traces of their activities helped us conduct the individual self-confrontation interviews immediately after the race. The self-confrontation interviews were designed so that rowers were asked to "re-experience their race" (i.e., re-enact their race) in order to describe and comment on the very details of the dynamics of their lived experience at each instant of the race (i.e., what they were doing, feeling, thinking, perceiving; see Theureau, 2003, for further details). Based on this verbalization data set, we were able to further characterize how the participants experienced each stroke. Each interview was fully recorded using a video camera so we able transcribe the verbal data and synchronize the rower's verbalizations collected during the self-confrontation interview with the corresponding oar strokes. Each individual interview lasted 1 h.

Behavioral Data Collection

The behavioral data were obtained from collection of mechanical data during the race using the *Powerline* system (Peach Innovations, Cambridge, UK) at 50 Hz (Coker et al., 2009). This system is imperceptible to rowers, thus allowing them to perform in natural conditions, but in an instrumented boat. In line with the study's aim, the system has a data acquisition and storage center connected to different sensors that allow to collect (a) the force applied to the oarlock by each rower (i.e., in the direction of the longitudinal axis of the boat), (b) the changes in each oar angle in the horizontal plane (i.e., the angle formed by the oar with the perpendicular axis to the longitudinal axis of the boat) and (c) the boat velocity and acceleration, via an accelerometer and a speed sensor fixed under the middle of the boat's shell (see **Figure 1**). The accuracy of the force and angle sensors was 2% of full scale (1500 N) and 0.5°, respectively. The calibration of sensors was carefully checked before the experiment. The "drive" portion of a given stroke takes place in the water and propels the boat; it begins with a minimum oar angle (i.e., the catch) and ends with a maximum angle (i.e., the finish). Conversely, the "recovery" reflects the portion of the stroke that occurs out of water (Hill, 2002).

Data Processing

Building the Individual Courses-of-Experience

To perform the empirical phenomenological description of the crew joint action, we mobilized the course-of-action framework. This framework is rooted in the enactivist approach, and it offers valuable analytic tools to operationalize the phenomenological claims of enactivism. Tightly linked to the phenomenology of Sartre (1958), the course-of-action analytical approach includes sophisticated accounts of the pre-reflective self-consciousness reported by the participants, allowing for a step-by-step analysis of the dynamics of the lived experience involved in the activity under study (Theureau, 2003).

In this light, verbalization data obtained from the interviews were fully transcribed and then synchronized in a **Table 1**. We then systematically reconstructed the 'course-of-experience' of each rower during the race from the verbalization data sets (Theureau, 2003) by identifying the chaining of phenomenological experiential units across time. A course-of-experience accounts for what is meaningful to the actor at each instant of the race. Phenomenological experiential units chained together over time thus provide a detailed description of the dynamics for a given actor. Considering the hypothesis of the course-of-action framework, a phenomenological experiential unit does not directly result from the verbalization data, but is built by the researcher based on this data. The researcher identifies the six components of each phenomenological experiential unit (i.e., the so-called hexadic sign, Theureau, 2003) that are assumed to merge at a given instant to form what the participant lives intrinsically as a syncretic experience. A given phenomenological experiential unit lasts until another unit begins from the point of view of the actor; its duration thus depends on the intrinsic sense-making dynamics of the rower. For instance, in the present study, the delineated units were close to the duration of an oar stroke (or shorter), reflecting the importance of each cycle in experiencing the race.

The first component of a phenomenological experiential unit refers to a current action [i.e., Action (A)], defined as the fraction of activity that the individual can show, tell, or comment on at a given moment. This component is the closest to the syncretic experience of the actor in the situation. It is assumed to emerge as a physical action, a communicative exchange, or an interpretative act. The researcher identified this component within the verbalization data sets by determining what the participant was doing and what he was thinking. The second component refers to the current involvement [i.e., Involvement in the situation (I)], defined as the individual's concerns at a given moment. This component was identified within the verbalization data sets by identifying the participant's significant concerns in relation to the specific situation. The third component refers to current expectations [i.e., Expectations (E)], defined as what is expected by the individual in the situation at a given moment. It was identified within the verbalization data sets by identifying the participant's expectations about the current situation arising from his concerns and from the previous events in the setting (e.g., what result he/she was anticipating). The fourth component refers to knowledge elements [i.e., prior mobilized Knowledge (K)], defined as the individual's past knowledge that is relevant to the current situation. This component was identified within the verbalization data sets by identifying the prior elements of knowledge used by the participant. The fifth component refers to the perception [i.e., Perception (P)], defined as elements of the situation significant to the individual at a given moment. It was identified within the verbalization data sets by identifying what the participant considered to be a meaningful element of the situation. The sixth component refers to the construction, validation, or invalidation of knowledge, defined as the component of activity that modifies elements of knowledge at a given moment [i.e., Refashioned Knowledge (RK)]. This component was identified within the verbalization data sets by identifying what knowledge was being constructed, validated, or invalidated by the participant at the considered instant. For further details on the method or the framework, see Theureau (2003). **Table 1** provides an example of each of these components [i.e., Action (A), Involvement in the situation (I), Expectations (E), prior mobilized Knowledge (K), Perception (P), and Refashioned Knowledge (RK)].

To enhance the coding process validity, the first, second, and the last author (who had already coded protocols of this type in earlier studies) randomly selected a 2-min sequence of activity for a crossed analysis. At this step, each researcher independently built the course-of-experience of each rower, and then compared their codes to identify disagreements. Any of these initial disagreements were resolved by discussion among the researchers, who debated their interpretations until a consensus was reached on the number of phenomenological experiential units and the contents of the six components of each unit. After this consensus was reached, the first author reconstructed the dynamics of the lived experience of each rower during the complete race. Remaining verbalization data that were doubtful or unclear were collectively re-processed. Then, the phenomenological experiential units were further aggregated to be processed through a thematic analysis of qualitative data (Braun and Clarke, 2006). The starting point of the thematic analysis was to characterize how each rower experienced each oar stroke in terms of joint action effectiveness (e.g., similarity of their sensation about the boat's glide, or about their global perception about the boat/crew functioning). This characterization was based on in a detailed examination of the six components of each phenomenological experiential unit, so that the extent to which rowers experienced joint action effectiveness was identified by the researcher in a comprehensive analysis of each instant of the race (see Supplementary Image 1). Such an analysis allowed

TABLE 1 | Example of the synchronization of the rowers' verbalization at the time code 00:40 [min:sec] of the race and their phenomenological experiential units filled regarding its six components.

Time code: 40 s	**Stroke Rower**			**Bow Rower**	
	Verbalization	**Six components**		**Verbalization**	**Six components**
Rower 1:	*Here, always good.*	**I**: To apply coach instructions/To hold on the back/Up hands on the front/To be synchronized with his partner/To have a maximum amplitude/To propel the boat. **E**: Be well synchronized with his partner/Row with a big amplitude/Maintain the boat pace. **K:** With the fatigue, he has trouble concentrating on the instructions. **P**: Coach instructions/feeling tired/Feel the boat as stable/Feel a good boat propulsion/Feel a well skiing of the shell. **A**: Feels the wind blowing on their back/Perceives the boat skiing. **RK**: *NI*	**Researcher**:	And now what about your feelings?	**I**: To drive well the boat/To keep the boat stable/To synchronize with his partner/Adapt to his partner/To put the same force as his partner during the oar stroke/To drag the boat as soon as possible/Be technically just in his movements **E**: Make a straight line with the boat/Be well synchronized with his partner/The boat should stay flat/Expects his partner grows as they usually do/Find ≪ the optimal intensity ≫ /Do not make technical fouls **K**: *NI* **P**: Feeling on the position of his body and its movements/sees the boat as stable **A**: Looks at the shoulders and hands of his partner/Puts on the same intensity as his partner/Perceives the boat skiing/Flexed his arm **RK**: Realizes that he made a technical error
Researcher:	Okay. Is this what you were thinking about at this moment? Or is it because you see the movie?		*Rower 2:*	*Here! We are already beginning to be a little more coordinated.*	
Rower 1:	*At this moment, I don't think about this. I thought to propel more and I already began to feel the fatigue.*		**Researcher**:	And what about your technical point of view?	
Researcher:	Ah Yes . . .		*Rower 2:*	*I see that my outer arm is not necessarily stretched. Normally, this arm must be stretched, but I keep it a little bent.*	
Rower 1:	*Yes, so at this moment, I did not necessarily think to tell me. . . I felt as if the boat were skiing.*		**Researcher**:	Do you say it to yourself when you are rowing at this moment?	
Researcher:	Okay. But did you really feel at this moment the boat skiing?		*Rower 2*	*Yes*	
Rower 1:	*Yes, I felt the boat skiing on the water.*		**Researcher**:	Well . . .	
Researcher:	Okay.				

I, Involvement in the situation; E, Expectations; K, prior mobilized Knowledge, P, Perception; A, Action; RK, Refashioned Knowledge. NI, not identified the researcher to decide how the rower experienced the joint action effectiveness, even if the rower was unable to detail such an experience in an explicit way. We were able to identify different individual typical modes of experiencing joint action effectiveness (i.e., from experiencing an effective to a detrimental joint action). From this local analysis, the first-order themes related to the joint action effectiveness experience were then merged step-by-step to give rise to second-order themes (see Braun and Clarke, 2006, for further details), which were the so-called typical modes of experiencing joint action effectiveness. Once these themes had been identified, each phenomenological experiential unit was labeled according to the theme to which it belonged, so that the chaining of the typical modes of experience might be analyzed across time.

After identifying and labeling the phenomenological experiential units, the next step consisted in time synchronizing the rowers' typical experiences. Such synchronization allowed scrutinizing the extent to which rowers simultaneously and similarly experienced the effectiveness of their joint action during the ongoing performance. At this step, typical arrangements of the modes of experience were scrutinized which allowed us to delineate portions of joint action dynamics (i.e., phenomenological data samples) that were congruent (or not) with the related lived experiences. The aim of the following next step was to search for the mechanical signatures of such delineated phenomenological data samples.

Computing Mechanical Indicators at Various Levels of Description

Mechanical indicators were calculated for each rower's stroke to account for individual-, interpersonal-, and boat-levels of description. These indicators were analyzed for each full oar stroke. Each stroke was decomposed into four phases to better assess changes within the mechanical signatures, specifically, the first and second halves of the drive phase (i.e., during the propulsive phase; when the oar was in water) and the first and second halves of the recovery phase (i.e., during the replacement phase; when the oar was out of water). Raw data (oar angles, forces applied to the oarlocks, acceleration and velocity) were filtered with a low pass Butterworth filter, with a 5 Hz cutoff frequency. Continuous angular velocities were then computed as the first derivative of the angular position, using the central difference formula. The continuous relative phase between oar angles of the stroke and the bow rower was selected to assess the interpersonal coordination (de Brouwer et al., 2013) and was calculated according to Hamill et al. (2000). Each cycle was considered between catch points as the local minimum of oar angle. Then, all the data were interpolated to 101 points per cycle. As the stroke rower's cycle did not start at exactly the same time that the one of the bow rower's, all studied rowing cycles were normalized on the stroke rower's cycle of oar stroke in order to allow for the comparison between rowers.

Individual level of description

To account for the individual level of description of the mechanical parameters, 11 indicators were selected: (a) the mean of force applied by the rower to the pin of oarlock in the direction of the longitudinal axis of the boat (N), (b) the standard deviation of the force's values (N), (c) the linear momentum of the force produced (kg.m.s^{-1}), (d) the peak force (N), (e) the peak force's timing in percentage of cycle (%), (f) the range of motion of the rowers (°), (g) the catch angle (°), (h) the mean of the angle of oar velocity (°.s^{-1}), and (i) the mean of the standard deviation of the values of the oar's angle of velocity (°.s^{-1}). Individual parameters were selected from the literature of performance analysis in rowing (Kleshnev, 2011).

Interpersonal level of description

To analyze the mechanical parameters at an interpersonal level of description, seven indicators were retained, which all accounted for a degree of synchrony of the oars strokes: (a) the mean of the angle's continuous relative phase (°), (b) the mean of the standard deviation of the angle's continuous relative phase, (c) the gap between the timing of either catch angles (%), (d) the mean of the gap between each individual peak force level (N), and (e) the gap between the timing of each individual peak force (% of the cycle). These parameters were selected to account for the level of synchrony between the angles of the rowers (Williams, 1967; Lamb, 1989; Hill, 2002) and between the exerted forces (Schneider et al., 1978; Wing and Woodburn, 1995; Baudouin and Hawkins, 2004).

Boat level of description

To account for the boat's level of description, two indicators were selected: the mean of the boat's velocity (m.s^{-1}) and the mean of the boat's acceleration (m.s^{-2}).

Identifying the Mechanical Signatures of the Typical Modes of Experience by a Subjectivity-Based Sampling Method

To combine phenomenological and behavioral data (i.e., typical modes of experiencing the race and the mechanical signatures at various levels of description), we performed a subjectivity-based sampling procedure. The procedure involved first scrutinizing the phenomenological data (i.e., the rowers' course-of-experience) to delineate the samples of behavioral data to be compared (i.e., various ways of experiencing the strokes give rise to various delineated sections within the race that will be further processed/compared). Such a subjectivity-based sampling method has been well developed in enactivist neuroscience (e.g., Rodriguez et al., 1999; Lutz et al., 2002; Lutz and Thompson, 2003; Froese et al., 2014a,b). To our knowledge, this has not been used in the field of human movement or sports science. The principle is to guide the observational study (e.g., brain dynamics observation, behavioral dynamics observation) using phenomenological data collected during the same task. This procedure includes the human experience as a valuable facet of the activity under study and investigates the observational (i.e., behavioral) measures that contribute to their emergence.

To utilize this method, the time code of each typical mode of experience was recorded (i.e., starting/ending point of the given mode) to identify all intervals falling under the same typical mode of experience, subsequently, we aggregated them in a corresponding sample. Various samples of mechanical data were built from this procedure (i.e., respecting the time codes of the typical modes of experience), each of them thus reflecting different ways of experiencing the joint action. Each instant of the joint action (i.e., each cycle) was further characterized in terms of the similarity of the individual experiences of the rowers, using the three individual modes of effectiveness experiences captured during the thematic analysis of each participant's activity. From the collective level of description of the lived experiences, we delineated four collective phenomenological categories (i.e., four samples) in our overall data set. Each of these categories comprised mechanical indicators measured for each cycle under consideration, resulting in multiple quantitative time series.

The first collective phenomenological category was labeled Simultaneously and Similarly Experienced as Meaningless (SSE-M). The second category was labeled Simultaneously and Similarly Experienced as Detrimental (SSE-D). The third category was labeled Simultaneously and Similarly Experienced as Effective (SSE-E). The fourth category was labeled Simultaneously Diverging Experiences (SDE).

Statistical analysis was carried out on the mechanical signatures of each of the four categories using the SPSS 17.0 statistical software package (SPSS, Inc., Chicago, IL, USA). Descriptive statistics were reported using the mean and the standard deviation (mean ± SD). Differences between the four categories regarding each mechanical indicator were analyzed using a multivariate analysis of variance (MANOVA). When the main effect was significant, ANOVA, or two-way ANOVA, with Tukey's HSD *post hoc* test was applied to the categories (SSE-M, SSE-D, SSE-E, and SDE) and the rowers (Rower 1 and Rower 2) as independent variables and the mechanical indicators listed above as dependent variables. *Post hoc* analyses were applied with Bonferroni correction. Data and ANOVA residuals were checked carefully for normal distribution using QQ plots. When distributions were not normal, a Kruskal–Wallis test was applied. When the Kruskal–Wallis tests were applied and revealed significant effects, Dunn's tests was applied, as *Post hoc* analyses, to identify the location of differences between categories (Dunn, 1961). The level of significance was set at $p < 0.05$.

RESULTS

Typical Individual Rowers' Modes of Experiencing the Joint Action Effectiveness

The thematic analysis performed on the individuals' phenomenological data showed that three main themes (i.e., revealing typical modes of experience) fit the collected data, suggesting three related recurrent ways of experiencing joint action effectiveness from the individual rowers' points of view. The most prevalent typical mode of experience (75.5% of the time of their individual activities) accounted for the units of experience in which the joint action was experienced as "meaningless" by the rower. "Meaningless" was used here as a label to signify that the rower did not pay attention to the joint action at the pre-reflective level of their activity. The second and the third typical modes of experience accounted for the units of experience in which the participant reported a "salient" experience of the joint action. Especially, the second typical mode (16.3% of the time of their individual activities) accounted for portions of activity in which the rower reported a salient, meaningful experience of contributing to an effective oar stroke, indicating that the joint action was experienced as being particularly "effective." The third typical mode of experience (8.2% of the time of their individual activities) accounted for portions of activity in which the rower reported a salient, meaningful experience of contributing to a poor oar stroke, thus indicating that the joint action was experienced as being "detrimental."

Collective Phenomenological Categories and Their Prevalence

The first collective phenomenological category was built by aggregating the data related to all cycles (i.e., oar strokes) that the participants simultaneously and similarly experienced as being "meaningless" ($N = 154$ cycles out of 204 cycles, representing 75.5% of the race). This category was labeled SSE-M. The second category accounted for all cycles that the participants simultaneously and similarly experienced as being "detrimental" for the joint action (labeled SSE-D; $N = 15$ cycles; representing 7.4% of the race). The third category accounted for all cycles that were simultaneously and similarly experienced by the participants as being "effective" for the joint action (labeled SSE-E; $N = 18$ cycles; representing 8.8% of the race). The fourth category accounted for all cycles that the rowers simultaneously experienced in a diverging fashion, and it was labeled SDE ($N = 17$ cycles; representing 8.3% of the race). See the illustration in **Figure 2**.

Mechanical Signatures of the Collective Phenomenological Categories at Three Levels of Analysis

The mechanical parameters related to the four identified categories (SSE-M, SSE-D, SSE-E, and SDE) were then submitted for further statistical analysis. The analyses aimed to identify the level of organization of the joint action (i.e., individual, interpersonal, or boat-level of the mechanical parameters analysis) that could at best explain the differences in the four collective phenomenological categories. For all of the following analyses, the comparison between the categories considered seven ways of analyzing the cycles: (a) the full cycle, (b) the drive phase, (c) the first half of the drive, (d) the second half of the drive, (e) the full recovery phase, (f) the first half of the recovery, and (g) the second half of the recovery.

Individual Level of Analysis

At the individual level of analysis, no significant differences between collective phenomenological categories was found in terms of individual mechanical indicators. The following indicators were assessed and did not capture differences between the categories: the mean force applied by the rower on the pin of the oarlock, the standard deviation of the force's values, the linear momentum of the force produced, the

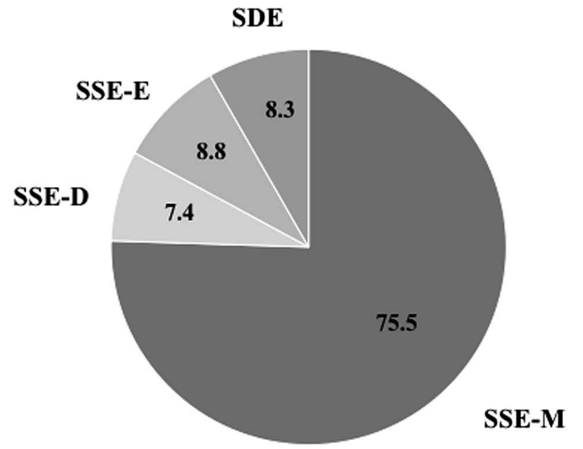

FIGURE 2 | Representation of the prevalence of the collective phenomenological categories during the race under study (in percentages). The percentage is the ratio between the number of cycle in each collective phenomenological category and the total number of cycle recorded during the race. SSE-M, Joint action Simultaneously and Similarly Experienced as Meaningless; SSE-D, Joint action Simultaneously and Similarly Experienced as Detrimental; SSE-E, Joint action Simultaneously and Similarly Experienced as Effective; SDE, Simultaneously Diverging Experiences of joint action.

peak force level, the peak force's timing in the percentage of cycle, the range of motion of the rowers, the mean of the angle of oar velocity, the mean of the standard deviation of the values of the oar's angle of velocity. See Supplementary Tables S1–S3.

Interpersonal Level of Analysis

At the interpersonal level of analysis, the values of the relative phase measures did not differ significantly between categories. The main result at this level of analysis was related to the measure of the gap between their peak force levels, which was significantly higher for the SSE-D than for the other collective phenomenological categories. Indeed, the Kruskal–Wallis test revealed an effect between the categories (chi-squared = 8.451; df = 3; *p*-value = 0.038), and Dunn's test then showed a significant difference between the SSE-D and the SSE-E categories (adjusted *p*-value = 0.026; see **Figure 3**). Thus, the measure of the gap between each individual peak force level appeared to be the best candidate to understand the mechanical parameters that supported a shared experience of effectiveness in joint action. See Supplementary Table S4.

Boat Level of Analysis

At the level of analysis of the boat, the results did not show differences between the four collective phenomenological categories for either of the indicators related to the boat, which were the mean of the boat's velocity and the boat's acceleration. See Supplementary Table S5.

DISCUSSION

The objective of the present study was to understand how individual experts in rowing experienced the effectiveness of their joint action when they rowed together at the first stage of their team coordination learning process. To achieve this objective, we collected the data related to their real-time lived experience (i.e., at a pre-reflective level of the activity) and to the related mechanical properties during a 12-min race. We were thus able to explore the mechanical signatures of various shared lived experiences. The discussion of the results is organized around our research questions. The results first suggested that (a) the extent to which rowers simultaneously experienced salient, meaningful sensations of effectiveness (i.e., effective or detrimental) in their joint action correlated with the extent to which supporting a mechanical signature captured expert-like pattern of team coordination. Secondly, the results also pointed out that (b) the participants spent a large amount of their activity not having a salient, meaningful experience of their joint action. These results are discussed regarding inter- and extra-personal regulation processes, respectively. We conclude by discussing the heuristics of an enactivist approach to social coupling in sports science.

The Mechanical Signatures of the Salient, Joint Experiences of Effectiveness

When considering instances in which both rowers simultaneously and similarly had salient experiences of their joint action at a given instant, we obtained two samples that reflected the identified collective phenomenological categories, and that consisted of the measured mechanical parameters. The first collective phenomenological category accounted for simultaneous salient experiences of an effective joint action, the second for a salient shared experience of a detrimental joint action. The comparison of both collective phenomenological categories showed significant differences within their mechanical signatures. On the one hand, the pattern of the joint action that was Simultaneously and Similarly Experienced as Effective (SSE-E) showed that both rowers produced their peak force at the same time and peak force levels were very close. On the other hand, the pattern of the joint action Simultaneously and Similarly Experienced as Detrimental (SSE-D) revealed that both rowers produced their peak force in the same time, but their peak force diverged in terms of level: the peak force of the bow rower was higher than the one of the stroke rower. Interestingly and consistent with what the rowing literature describes in terms of what is expected of a rowing crew coordination (Smith and Draper, 2002; Baudouin and Hawkins, 2004), the mechanical pattern related to the shared experience of effectiveness (SSE-E category) was more expert than the pattern related to the shared experience of a detrimental joint action (SSE-D category). Indeed, coxless pair-oar rowing requires a high technical level as the force pattern required is more complex than in other rowing boats (Smith and Draper, 2002): it requires a specific pattern of application of the force due to the position of the two rowers in the boat. In order to maintain the boat's direction, the

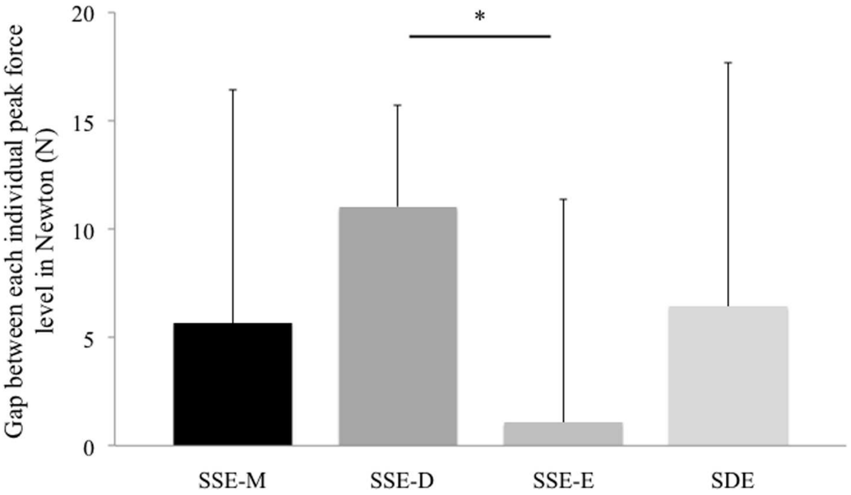

FIGURE 3 | Mean values and standard deviations for the gap between each individual peak force level in each identified subjectivity-based sample. The gap was calculated by subtracting the peak force level of the bow rower with the peak force level of the stroke rower (i.e., a mean near 0 or negative is closest to the expert pattern). SSE-M, Joint action Simultaneously and Similarly Experienced as Meaningless; SSE-D, Joint action Simultaneously and Similarly Experienced as Detrimental; SSE-E, Joint action Simultaneously and Similarly Experienced as Effective; SDE, Simultaneously Diverging Experiences of joint action. Statistical significance was set to $^*P < 0.05$

stroke rower has to produce his peak force slightly earlier than the bow rower does and with a peak force higher than that the bow rower (Smith and Draper, 2002; Baudouin and Hawkins, 2004). In this light, our results showed that the gap between the peak force level of the stroke and the bow rower was significantly more important when the rowers similarly experienced their joint action as detrimental, but this gap was inverted compared to expert patterns (i.e., bow rower's peak force level was higher than that the one of the stroke rower). Joint sense making thus appeared to be nested in the behavioral facet of the joint action in that the extent to which rowers shared experience of effectiveness was related to the extent to which their mechanical patterns signed expert team rowing.

Moreover, while experiences of joint action were quite accurate in terms of the mechanical states from which they emerged (see the Section "Results" discussed above) our results pointed out that these experiences were still capable of improvement. Indeed, at a pre-reflective level of the activity, the rowers did not perceive that their joint action states were not perfectly achieved in terms of what is expected for a coxless pair crew. Additional mechanical indices supported this interpretation: the analysis of the rower's peak force showed that this peak was produced a little bit late by the stroke rower (around 1%; see **Figure 4**), as required in the rowing literature (Smith and Draper, 2002; Baudouin and Hawkins, 2004). This finding implies that rowers were not fully aware of the team coordination patterns that shaped their joint action and supported their lived experiences, suggesting that future research should address avenues related to the unperceived features of team coordination phenomena (e.g., Varlet and Richardson, 2015), especially how these features can change through training practice.

In sum, the gap in the rowers' peak force levels shaped the emerging shared experiences of effectiveness, which indicates that the *interpersonal* level of mechanical description was the one that best accounted for the extent to which rowers experienced their joint action effectiveness at the pre-reflective level of their activity. Interestingly, by pointing out that rowers managed the continuity/change of their joint action from the interpersonal states of coordination they perceived, our study indicates that an "inter-personal" regulation mode might structure how each rower manages the joint action. The Inter-personal mode of regulation refers to individual activities that are synchronized through informational constraints relied on by the given actors. For example, this mode of regulation is implied in studies where participants are asked to synchronize their oscillating limbs and to actively regulate the emergent states of coordination on the basis of the extent of synchrony they perceive on-the-fly. Such inter-personal regulation processes have been investigated in lab-based studies regarding inter-arms coordination between participants (Davis et al., 2016), for inter-legs synchronization (Schmidt and Richardson, 2008), or in natural settings regarding inter-oars' stroke coordination in rowing (Wing and Woodburn, 1995) or inter-players' trajectories coordination in basketball (Esteves et al., 2011). In terms of the experience that each actor has in his actor–environment coupling, such a regulation mode assumes that actors remain sensitive to the dynamic behavior of the partner, and that they adapt in this regard, as found in the present study from the analysis of the salient, meaningful shared experience of joint action effectiveness. The following "Results and Discussion" Sections will counterbalance such a conclusion by suggesting that "extra-personal" modes of regulation might

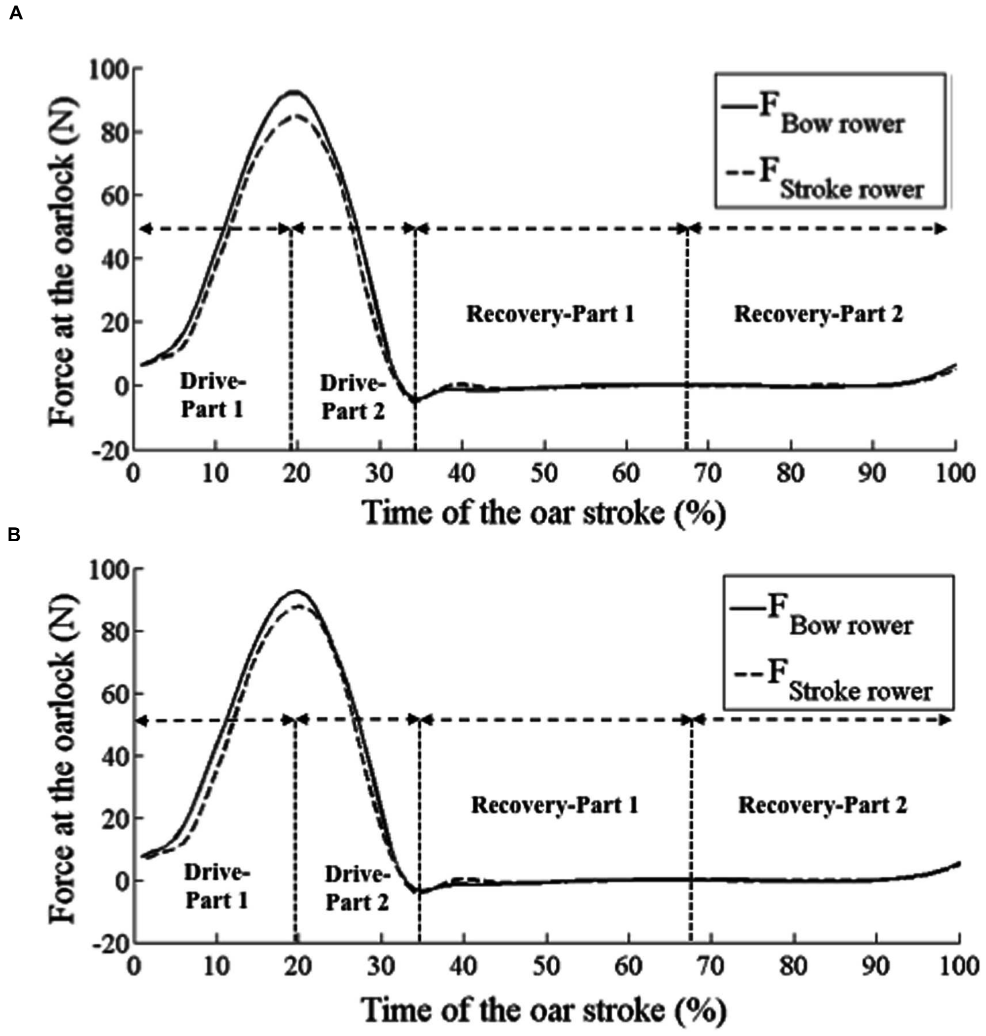

FIGURE 4 | (A) Representation of the force mean at the oarlock time curve of a typical oar stroke experienced as detrimental and **(B)** representation of the force mean at the oarlock time curve of a typical oar stroke experienced as effective for bow and stroke rowers.

have shaped some remaining portions of the race (i.e., SSE-M category).

While having an individual salient, meaningful experience of effectiveness in a joint action did not guaranteed that this lived experience was similar to that of the teammate or that it was related to expert-like mechanical signatures, our results supported the idea that when an experience was shared, it was likely to emerge from an efficient joint action. However, there was a notable size difference between experiential categories (e.g., between SSE-M and the other experiential categories). This difference in the size of the collective phenomenological categories could be the reason it was difficult to obtain significant results at the mechanical level.

Participants Did Not Make an Extensive Salient Experience of Their Joint Action

Beyond the analysis focused on the shared salient experiences of different degrees of effectiveness, the analysis of the phenomenological data provides elements to counterbalance the "inter-personal" mode of regulation suggested above. To this end, the prevalence of each typical mode of experiencing the joint action (i.e., each collective phenomenological category) needs to be considered. Joint action was perceived simultaneously as a salient, meaningful experience for only 24,5% of the race under study. With respect for this typical mode of experiencing joint action as salient, of note is that 8.3% of which was associated with diverging experiential content (i.e., the joint action's degree of effectiveness was simultaneous and salient but not similarly experienced), and 16.2% with similar experiential contents. In the latter case, the rowers could simultaneously and similarly report a salient, meaningful experience of a given stroke as effective or detrimental to their joint action (i.e., SSE-E and SSE-D categories), as extensively discussed in the previous section. Finally, the results showed that, at the pre-reflective level of their activity, the rowers did not pay attention to the effectiveness of their joint action for the remaining 75.5% of the studied period, indicating that the rowers did not make an extensive salient experience of their joint action at the scale of the overall race (see the distribution of the collective phenomenological categories during the race in **Figure 5**). In other words, and as labeled in the thematic analysis of the phenomenological data, the rowers were able to coordinate their strokes through experiencing their joint action as "meaningless" during a large part of their crew activity.

Thus highlighting that the joint action generally was not explicitly lived as a salient experience within the dynamics of the rowers' activity might be considered unexpected. Indeed, by revealing the prevalence of implicit team processes at the early stages of a team coordination learning process, this result is controversial in that it does not support the implicit coordination process hypothesized by Eccles and Tenenbaum (2004) in sports team learning, which viewed the learning of team coordination as a linear process progressing from explicit processes toward implicit and embodied processes. At least, our present findings suggest that team coordination in rowing seems to be a task, which can be performed by individual experts in rowing without their exhibiting an extensive intentional/explicit activity of co-regulation of their joint action.

With respect to the discussion about the modes of regulation that underlie the present joint action (e.g., an "inter-personal" mode of regulation), and in indicating that interpersonal states of coordination were not the constant focus of the adaptations actively performed by the rowers, our observations now suggest that extra-personal regulation processes might also have underlain the joint action dynamics (Millar et al., 2013). Extra-personal regulation has been used to explain the emergence of team coordination patterns while rowers were only regulating their individual coupling to the environment separately. The environment is thus used by individuals to mediate/organize the arrangement of individual activities at each moment of the collective activity. This process differs from inter-personal regulation processes that are grounded on a direct co-regulation of the joint action dynamics itself. When a rower is involved in an extra-personal regulation and acts on his/her oar, he/she can adjust his/her movements in response to the reaction of the water and the boat information. Both rowers can thus respond similarly, thanks to this mediation. Interestingly, as observed within social insects that act together through environmental mediation (e.g., termites, ants), such a process does not need individual agents to be aware of the collective motion to which they are contributing, which might thus explain the very few instances in the present study where the rowers made salient, meaningful experiences of their joint action.

Remembering that the analysis of the shared salient experiences of effective/detrimental oar strokes suggested that the rowers' regulation processes were rooted in the inter-personal level of organization, the additional finding notes that the rowers did not make an extensive experience of their joint action for a large part of the race. This finding thus suggests that the rowers used an extra-personal regulation process to regulate their coordination in the portions of the race when joint

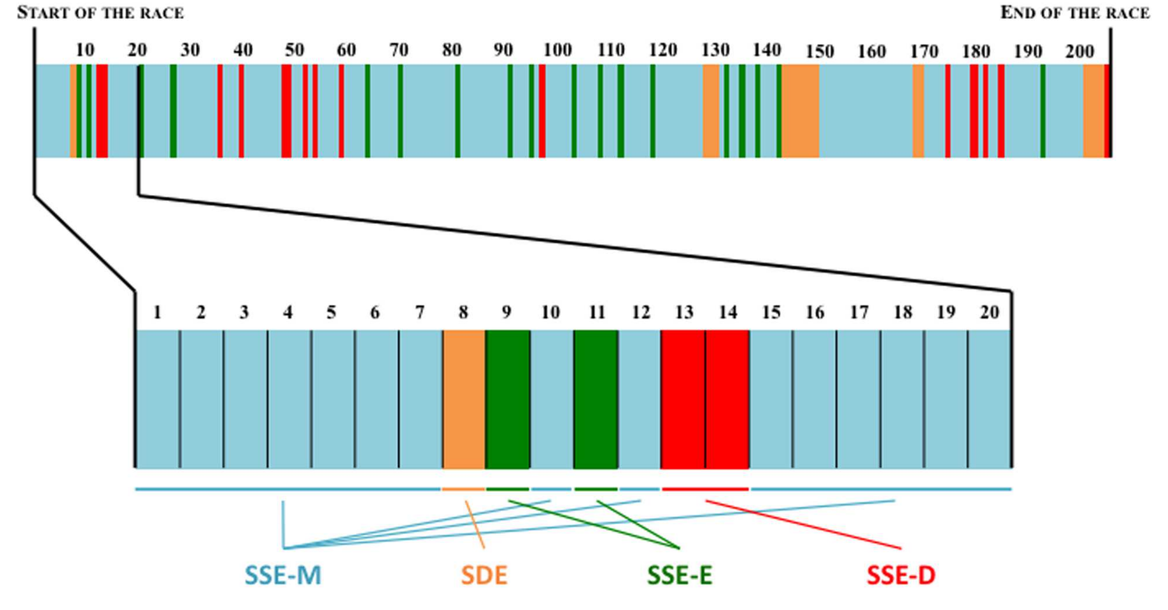

FIGURE 5 | Overview of the repartition of the collective level of description of the lived experiences throughout the race.

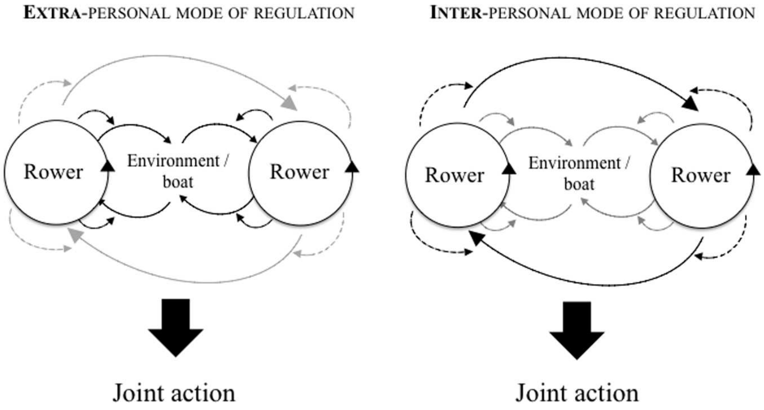

FIGURE 6 | Illustration of both of the suggested modes of regulation used by the rowers (From an initial representation proposed by Froese and Di Paolo, 2011).

action was experienced as "meaningless." One can then question how the extra-personal regulation process suggested here can combine with the inter-personal mode of regulation captured earlier. We assume that, when rowing alone, expert rowers learn to regulate their activity through the boat's information (Millar et al., 2013), which allow them to row with others using an extra-personal mode of regulation, even if they have no prior shared team practice. However, along the coordination process under study, some events occurred at the inter-personal level of organization (i.e., synchronization breakdowns) to which the rowers were sensitive, causing them to exhibit an inter-personal mode of regulation at the level of the activity that was salient and meaningful to them (see **Figure 6** for an illustration of the two suggested modes of regulation). This latter mode, even being less prevalent, might be the mode that they use to manage their progression, the mode they use to maintain/change the flow of their joint action effectiveness. Thus, to hypothesize what might be observed later in the future stages of learning their joint action, two alternative transformations might be evidenced: (a) rowers will increase the proportion of cycles lived as "meaningless" (i.e., SSE-M), thus signing an increasing extra-personal mode of regulation of their continuous joint action. At the same time, they maintain an inter-personal mode of regulation to manage race events, evidenced through momentary salient experiences of joint action effectiveness that is rooted in interpersonal mechanical states; or (b) rowers will also gradually learn to regulate the sudden events through an extra-personal mode of regulation, evidenced through salient experiences of joint action effectiveness that is rooted in the boat's mechanical variation. In this light, future research should investigate the extent to which rowers are supposed to share more salient meaningful experience through team training, considering the nature and the transformation of the information that support such experiences. Such research should be able to better challenge the Eccles and Tenenbaum's (2004) hypothesis that assumes a hypothetical pathway from explicit to implicit regulation processes in team coordination learning.

Interestingly, our study also revealed that when rowers simultaneously experienced a salient joint action, their experience was not necessarily similar. However, such dissimilarities in the simultaneous experiential content did not appear to link with any decrement in the mechanical measures. Our suggestion is that, as long as rowers experienced simultaneously their co-regulation of the joint action, the joint performance did not suffer from each rower judging effectiveness differently. This corroborates that team coordination patterns of movement may occur without a perfectly shared experience about the ongoing joint action (Bourbousson et al., 2011, 2012). Other studies have indicated that joint action was quite resilient to perfectly shared experiences, especially in those that used the perceptual crossing paradigm (Auvray et al., 2009). This device puts two actors in situations where they have to move an avatar in a virtual environment populated by different entities (avatars of humans and various lures), visually empty but providing tactile stimulation at each encounter through the mouse used by the participants. Interestingly, what helps participants to experience social connectedness, and subsequently to succeed in finding each other, is the ongoing co-regulation process they both perceived simultaneously (Froese et al., 2014a), disregarding the extent to which each actor was satisfied by the unfolding interaction, since they have no feedback on their current effectiveness in the task. In agreement with the findings obtained in such experimental studies, the present study provided further evidence that the full coordination of sense-making activities is not needed to allow for a viable patterned joint action in a natural task, as long as actors are simultaneously involved in co-regulating their collective behavior (Froese and Di Paolo, 2011; Froese et al., 2014a,b). Thus, as recently introduced as a hot topic in sports team coordination research (Araujo and Bourbousson, 2016), future research should consider the ways in which the extrinsic facet of the coordination process (e.g., the behavioral facet) and the phenomenological facet are mutually constrained to give rise to collective effectiveness in a task. Regarding training concerns, future research should consider how shared repeated practice of joint action (i.e., through the development of team coordination expertise) might change step-by-step the relationships that shape both facets.

Insights into Team Coordination Phenomena in General

Beyond our hypotheses, the results of the present study offer some insights into team coordination phenomena in general. First, the team members combined two ways of regulating their joint action throughout the race, namely a meaningless regulation and a salient, meaningful regulation of the joint action. While such a distinction has been proposed by Eccles and Tenenbaum (2004) in their framework for team coordination in sports, related research questions remain open to understand the effectiveness of such regulation processes, as illustrated by the present results, which challenge this theory. Second, the team members also combined two distinct modes of regulation, inter- and extra-personal. While such a distinction has been suggested in human movement science (e.g., Millar et al., 2013), very little is known about how both modes of regulation might co-occur during a given ongoing joint action.

Considered together, these distinct regulation processes call for three main avenues in team coordination research. Firstly, research should question the settings' characteristics that are particularly propitious for one of these processes. For instance, the environmental mediation possibilities might call for a prevalence of extra-personal regulation. Also, the number of participants involved in the collective behavior might make the inter-personal regulation process hard to manage (i.e., each participant cannot regulate all the dyadic linkages included in the collective), so that extra-personal processes might become parsimonious and preferable when environmental mediation is available. Secondly, research should question to what extent training practices could change regulation, and for which benefits such transformations might occur. Thirdly, research might identify the parameters that control how actors switch dynamically from one regulation process to another during an unfolding joint action.

Beyond the need for team coordination research not only to focus on the behavioral facet of the joint effort, but also to investigate the underlying modes of intentional regulation, our opinion is that future avenues will benefit from considering hypotheses included in the stigmergic theory of collective behavior (Susi and Ziemke, 2001; Avvenuti et al., 2013) in which holistic phenomena of coordination might be considered as emerging from the behavior–environment coupling. Stigmergic theory of collective behavior explains how each agent of the social system regulates its own behavior–environment coupling, without the agents needing to actively and directly coordinate with other agents, and without them needing to be aware of these cooperating agents. Of interest is that no evidence of such processes has been discussed extensively in human collective behavior. The scarce references made to such collective behaviors (e.g., Bourbousson et al., 2012; Silva et al., 2014) have neglected the stigmergic hypothesis and instead have adopted the local-and-distributed mode of coordination, i.e., humans can exhibit a patterned collective behavior without needing to grasp the global properties of the social structure to which they contribute. When considering that stigmergic processes do not require the actors to be aware of the collective behavior (e.g., like social insects that do not experience a sense of working together), then stigmergic processes could explain why in this study, the rowers were in synch for the three quarters of the race without simultaneously having a salient, meaningful experience of their joint action effectiveness. For instance, when the extra-personal mode of regulation (i.e., stigmergic) is needed to become an expert crew in rowing, it also seems to operate easily in a novice crew (despite their intentional subjective regulation being shaped by inter-personal processes). Such stigmergic processes could also explain why the rowing training theory (Morrow, 2011) does not consider the step-by-step adjustments of team coordination as a time consuming part of the training. It could also explain why rowing crews are often composed late in the sporting season, because of members' interchangeability are facilitated when actors coordinate through the environment (in comparison to the increased member-dependence obtained through inter-personal regulation processes). At least, the present study suggests ways for future research to delineate strengths and weaknesses of the regulatory activities that facilitate the emergence of collective behavioral patterns.

The Heuristics of an Enactivist Approach to Social Couplings

Beyond our hypotheses and methodological aims, the results of the present study provide the opportunity to explore the potential of the enactivist approach to social couplings (Laroche et al., 2014; Araujo and Bourbousson, 2016). We believe the approach offers benefits to research in this area. First, this framework is constructivist, linked to a dynamic approach to behavior and to an additional phenomenological epistemology (Thompson, 2011). The framework is concerned with combining an understanding of team coordination from an external point of view (i.e., mechanical measures) with an understanding of the (inter)subjectivity that shapes/is shaped by this behavioral facet (Petitmengin and Bitbol, 2009). The phenomenological assumptions included in this framework were thus useful for capturing in detail the actors' experiences at each instant of the joint action. By comparing the individual situated experiences of the rowers, the researchers were able to characterize the dynamic properties of team members' participation in joint sense making (De Jaegher and Di Paolo, 2007) and the specific timing and sequencing of such lived experiences. As performed in the present study, this subjectivity-based description guided the subsequent processing of the behavioral data. In this light, we used the lived experiences of rowers to delineate various collective phenomenological categories and the related behavioral samples sets that were then compared statistically. This procedure, inspired by works conducted in the area of enactivist neurosciences (e.g., Lutz et al., 2002), has been referred to as a subjectivity-based sampling method.

The subjectivity-based sampling method provided three opportunities. It allowed us to process quantitative and behavioral data only, which *de facto* included the phenomenology that prevailed in such data. However, as is usual in behavioral research, the processed team coordination data (i.e., the explained variable) include mostly the experimental condition, specifically external/contextual constraints that have been observed (i.e., the explanatory variables). The procedure performed in our study guided the mechanical analysis of the phenomenological data, and thus ideally illustrated how a full enactivist approach could be used with behavioral data. The subjectivity-based sampling appeared to be a good method for interdisciplinary research. Moreover, by including a phenomenological methodology that uses retrospective interview techniques, the research design permits activity to be studied based on the reconstruction of the natural and specific conditions of the activity to reveal how participatory sense-making develops in a real-world setting. Finally, the present method instantiates the concept of human movement as a place of interplay of behavioral and phenomenological facets (Froese and Di Paolo, 2010), and a concept of team coordination as a simultaneous combination of the behavioral dynamics of a joint effort (i.e., non-accidental correlations between the movements of the participants) and participatory sense-making dynamics (i.e., each participant constraining the own-world of the other). The present study illustrates the interiority of individuals that is not always captured by objectivist approaches. Here, taking into account lived experiences helped to make sense of variability in the objective data, and illustrated how this interiority might be the starting point to describe actor/environment coupling, including actor/actor coupling. However, the subjectivity-based sampling method should be strengthened by future research in order to better identify its domain of relevance, that is the particular setting in which an elicitation of actors' lived experiences heuristically complements behavioral analyses.

CONCLUSION

Our study leaves some open questions. In this study, extra-personal regulation processes have been suggested for most of the race, but instances of intentional inter-personal regulation processes might also be suggested, as similar salient, meaningful lived experiences of joint action effectiveness were explained by mechanical parameters, accounting for an inter-personal level of organization. Further research could be conducted with the same methodology (a) to extend the heuristics of a subjectivity-based sampling method and (b) to address the question of dynamic changes in the intentional modes of regulation during races or in more advanced training sessions. When one assumes that rowers learn to be an expert team by actively regulating and coordinating their activity based on what they experience as being effective, then one can question how such behavioral changes may occur without rowers having a pervasive lived experience of their joint efforts. Thus, a promising question may be to focus on team coordination training, first, by addressing how such a practice may progressively change the saliency of the participants' lived experiences of joint action and second, by addressing how it may change the behavioral signatures in which those lived experiences are anchored. Together, these questions of interest suggest that integrating lived experience with the investigation of joint action is likely to improve our understanding of how actors regulate their interaction in real time to facilitate stable and optimal forms of social functioning.

AUTHOR CONTRIBUTIONS

MR'K and JB have made substantial, direct and intellectual contribution to the work, and approved it for publication. JS and MD made substantial contributions to the analysis and the interpretation of the data. They also gave final approval of the version to be published.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2016.00720

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DEUXIÈME PARTIE

LA TRANSFORMATION DES ANCRAGES INFORMATIONNELS SOUS L'EFFET DE CONTRAINTES EXTERNES

ÉTUDE 2

JOINT ACTION IN AN ELITE ROWING PAIR CREW AFTER INTENSIVE TEAM TRAINING: THE REINFORCEMENT OF EXTRA-PERSONAL PROCESSES

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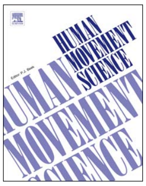

Full Length Article

Joint action in an elite rowing pair crew after intensive team training: The reinforcement of extra-personal processes

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ABSTRACT

The present study is a follow-up case report of the study from R'Kiouak and colleagues (2016). From the initial study that analyzed how individual experts rowed together while they never had practiced together, we seized here the opportunity to investigate how both rowers synchronize after having intensively practiced joint action through a national training program in which they were invited to take part. The joint action of 2 individual expert rowers, which composed a coxless pair crew, was tracked on-the-water at the end of a team-training program. We first determined how each rower experienced the joint action at each instance of oars' strokes during a 12 min race. A phenomenological analysis evidenced several categories of how rowers shared lived experiences of their joint action. From mechanical data captured through an automatic recording device, we then scrutinized the mechanical signatures that correlated with each phenomenological sample. By comparing the present case report to the initial study, results suggested that, after the training program (a) rowers shared more meaningful experience of their joint action, and (b) only the boat velocity's index contributed to explain why oars stroke were alternatively lived as effective or detrimental. The present case report thus suggests that joint action training in rowing might imply an increase in the joint sense-making activities, probably associated with a change from an inter-personal to an extra-personal meaningful mode of co-regulation of the joint action.

1. Introduction

Human collective behaviors emerge in part thanks to synchronization processes. To create, maintain and/or disrupt such synchronization, individuals regulate their behaviors with regards for what they perceive as the emerging needs of the collective activity (Bourbousson & Fortes-Bourbousson, 2016). Based on how they experience the accuracy of their real-time activity, humans adapt online by maintaining or changing their involvement. This adaptive and regulatory activity allows to obtain the states of Actor(s)/Environment (A/E) coupling that are required/expected regarding the current joint task (i.e., collective coordinative task). In the literature two very distinct processes can be found that ground the way interactors regulate their joint action, which are the inter- and extra-personal modes of co-regulation (R'kiouak, Saury, Durand, & Bourbousson, 2016).

First, the *"inter-personal" mode of co-regulation* accounts for individual activities that are synchronized through informational resources that are available *between* the given actors. In other words, each participant guides his/her own action and how he/she adapts to the current needs of the joint action by taking into account the behavior of his/her teammate and/or the resulting states of dyadic synchronization. In terms of the experience that each teammate makes of his/her A/E coupling, such a co-regulation implies

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that teammates are sensitive to the dynamic behavior of the partner and adapt it in this regard. For example, this mode of co-regulation is implied in interpersonal coordination of movements when participants are asked to move their limbs to achieve some expected states of dyadic synchronization (see Gipson, Gorman, & Hessler, 2016; Schmidt & Richardson, 2008 for reviews).

Second, the *"extra-personal" mode of co-regulation* accounts for participants adjusting the dynamics of their activity through informational resources that are available in their material and physical environment, without regard for the behaviors of the other participant(s). Such a mode of co-regulation has been well documented by Grassé (1959) in the *stigmergic* theory in the animal world. To illustrate, Grassé explained how social termites' behaviors could exhibit complex collective properties without a direct between-agents synchronization being needed (Christensen, 2013; Dipple, Raymond, & Docherty, 2014; Susi, 2016; Theraulaz, 2014), and even without co-agents being aware of others' activities. Such processes require that traces of others' activities are made available within the environment or a material as the boat in rowing (Millar, Oldham, & Renshaw, 2013), and the interactors needing only to be dynamically aware of such environmental traces.

Studies in human movement science have mainly described the inter-personal mode of co-regulation, and to a lesser extent explored the stigmergic approach, even though they have suggested that discussing extra-personal mode of co-regulation should be of promising interest (Avvenuti, Cesarini, & Cimino, 2013; Millar et al., 2013). To our knowledge, only one empirical study has been conducted that explored the way in which inter- and extra-personal modes of co-regulation can both occur in human collective spatiotemporal behaviors (R'kiouak et al., 2016). Adopting an enactivist approach to social coupling (Laroche, Berardi, & Brangier, 2014), the authors tracked both modes of co-regulation in a real-world rowing setting. R'kiouak et al. (2016) selected expert rowers that never practiced together and pointed out that both modes of co-regulation seemed to be alternatively achieved by the rowers in their ongoing adjustments, while each of them being inferred from distinct levels of consciousness.

To infer the given modes of co-regulation from the data, authors first performed a qualitative analysis of the lived experiences of rowers at each instant of the race, and then scrutinized the mechanical correlates of how they experienced the effectiveness of their joint action. For the most part of the race under study, the joint action of the crew was meaningless for both rowers at the level of the pre-reflective experience of their activity (i.e., the rowers did not pay attention to their joint action), while the mechanical indicators of boat velocity and coordination did not exhibit any synchronization impairment. Since no salient, meaningful experience of joint action supported these portions of the race, the results thus led authors to assume that crew coordination could be achieved through extra-personal processes in such a case. Interestingly, when the given rowers sometimes simultaneously experienced their joint action as salient, meaningful to them, the mechanical indicators that at best contributed to explain differences between strokes experienced as effective *versus* detrimental were found at the inter-personal level of analysis. In such portions of the race, authors thus proposed that meaningful inter-personal processes might have occurred, in place of the meaningless extra-personal processes that were proposed each time joint action was meaningless to them. The authors (R'kiouak et al., 2016) thus concluded that both rowers under study were capable of actively co-regulating their joint action using a meaningful inter-personal mode of co-regulation, and this mode occurring on a background of meaningless extra-personal mode of co-regulation. Based on an opportunity to renew the investigation with the same unique crew, the present study was built from these initial findings.

The present investigation replicated the same design, and was carried out with the same participants, after a national team-training program in which they were invited to take part. During the program, the rowers were intensively trained to row together, while they never had rowed together before (i.e., at the time of the initial study, called "pre-program race" in the next sections). Following principles of an action research-like design (Chein, Cook, & Harding, 1948; Whitehead & McNiff, 2006), the present study (called "post-program race" in the next sections) was conceived as an evaluation of the effects of such a program, and offered the training staff the opportunity to diagnose their interventional effects. In terms of scientific objectives, the present follow-up case report investigated how changes in inter- and extra-personal modes of co-regulation of joint action could be inferred from a mixed data design applied to a single test race, occurring after an intensive team training practice.

Our hypotheses are based on the results of previous studies that have suggested that experts can adopt a pronounced extra-personal mode of co-regulation, through a regulation of their joint action that becomes mainly meaningless (Millar et al., 2013). In this way, we hypothesized a transformation of the rowers' joint action co-regulation in terms of (a) an enhancement of the meaningless extra-personal mode of co-regulation, as observed by an increased proportion of the race in which joint action was meaningless, and (b) a qualitative change of the meaningful co-regulation processes exhibited by rowers, evolving from inter-personal to extra-personal nature, as observed by boat level indicators being the best candidates to explain differences in salient, meaningful experiences of effectiveness by the rowers (Millar et al., 2013). Together, these expected results prognosticate both rowers having being trained to perform joint action in a more ubiquitous extra-personal mode of co-regulation, being both meaningless and meaningful.

2. Method

2.1. Participants and procedure

A junior men's coxless pair (age: 17 years) participated in this study, with the bow rower seats to the bow of the boat and the stroke rower seats to the stern of the boat (see Fig. 1). Both participants were the same as in the initial study that served as a comparison point for the present investigation (R'kiouak et al., 2016). The data collection occurred in a single 12 min race at 18–19 strokes per min (spm) after rowers took part to an intensive national team training program that lasted one-and-an-half-month and that was conducted by the national staff. This training period consisted in 22 sessions of joint crew rowing (each of them lasting around 1 h), tightly managed by the national coach that provided individual and crew on-water feedbacks. Participants, the persons

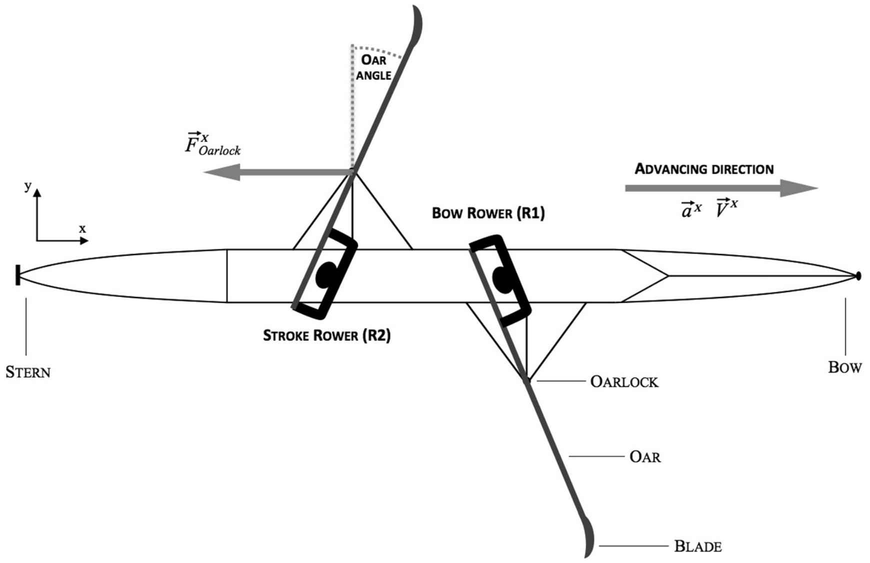


Fig. 1. Bird's-eye view of a coxless pair. The onboard measurement system (Powerline, Peach Innovation) records the components of the forces applied by the rowers to the oarlock along the x-axis (in the direction of the boat's movement), the acceleration, the speed of the boat, and the angle formed by the oar with the y-axis (perpendicular to the boat's movement) adapted from R'kiouak et al. (2016).

in charge of the participants and coaches provided written informed consent. The protocol was approved by the local interdisciplinary Institutional Review Board of the sports sciences faculty.

2.2. *Data collection*

Similar to the data collection performed in the initial study (R'kiouak et al., 2016), phenomenological data that accounted for the pre-reflective self-consciousness of the participants was first recovered through individual post-activity self-confrontation interviews with each rower (Bourbousson, R'Kiouak, & Eccles, 2015). As a reminder the enactivist approach devotes special attention to pre-reflective self-conscious phenomena, that is, the implicit ways in which a given actor experiences his/her ongoing activity. These interviews were conducted through a step-by-step video watching of the race while asking rowers to "re-experience their race" in order to describe and comment on the details the dynamics of their experience at each instant of the race (see R'kiouak et al., 2016; Theureau, 2003 for further details). Based on this verbalization data set, we were able to further characterize how the participants experienced each stroke at the pre-reflective level of self-consciousness. Each interview was fully recorded using a video camera so we able transcribe the verbal data and synchronize the rower's verbalizations collected during the self-confrontation interview with the corresponding oar strokes. The duration of the self-confrontation interviews were about one hour and fifteen minutes.

Second, behavioral data was recovered using an automatic recording device that recorded mechanical data during the races under study (*Powerline* system, Peach Innovations®, Cambridge, UK) at 50 Hz (Coker, Hume, & Nolte, 2009). Three measures were collected: (a) the longitudinal force applied to the oarlock by each rower, (b) the oar angle in the horizontal plane (i.e., the angle formed by the oar with the perpendicular axis to the longitudinal axis of the boat), and (c) the boat velocity and acceleration (see Fig. 1). For the angle and the force an accuracy of 2% of the full scale was registered (i.e., 1500 N for the force and 0.5° for the angle; see Coker et al., 2009). We assume that the "drive" portion (i.e., when rowers propel the boat) begins with a minimum oar angle (i.e., the catch) and ends with a maximum oar angle (i.e., the finish) and conversely for the out-of-water "recovery" portion (Seifert et al., 2017). Based on the oar angle data, the drive and the recovery portions were then delineated in two halves (Feigean, R'Kiouak, Bootsma, & Bourbousson, 2017; Sève, Nordez, Poizat, & Saury, 2013).

2.3. *Data processing*

2.3.1. *Qualitative analysis of the phenomenological data*

First, the phenomenological data obtained from the verbalizations during interviews were transcribed. We then reconstructed the 'course-of-experience' (i.e., the pre-reflexive consciousness) of each individual rower during the race. This procedure consisted of identifying step-by-step phenomenological experiential units chained together over time. A course-of-experience thus provides a tooled description of the phenomena experienced as meaningful by a given participant at each instant of his real-time activity (R'kiouak et al., 2016; Theureau, 2003). It thus allows a phenomenological account performed in the detail, as it allows for identifying the specific moment at which a given lived experience has occurred. Once the temporal chaining of the phenomenological experiential units was performed for each rower, both course-of-experience were further submitted to a thematic analysis

(Braun & Clarke, 2006). Thematic analysis was conducted according to standards in qualitative research; it is dedicated to capture recurrent themes that structure the phenomenological data. In the present study, it allowed to gain in generality about how each oar stroke was experienced in terms of joint action effectiveness, and to open up possibilities of comparison between individual rowers singular experiences (see Fig. 2). To perform the thematic analysis, we considered how joint action effectiveness was experienced as the criterion that drove the data schematization, defined as the extent to which rowers experienced the current state of crew functioning as needing to be changed/maintained. Through this process, typical (i.e., recurrent) experiences of joint action effectiveness were identified (i.e., considered themes) and each phenomenological experiential unit was re-labeled according to the typical experience to which it belonged (see Fig. 2). Next, the rowers' typical experiences were time synchronized in order to scrutinize to which extent rowers simultaneously and similarly experienced the effectiveness of their joint action during the ongoing performance (cf. Fig. 3).

2.3.2. Computing mechanical indicators at various levels of analysis

The raw data were filtered with a low pass Butterworth filter, with a 5 Hz cutoff frequency. To have a common starting point, all cycles were delineated regarding the stroke rower's oar stroke. Each cycle was interpolated to 101 points per cycle in order to allow inter-cycles comparisons. Mechanical indicators were processed on each stroke regarding seven cycle's scales that were (a) the full cycle, (b) the drive phase, (c) the first half of the drive, (d) the second half of the drive, (e) the full recovery phase, (f) the first half of the recovery, and (g) the second half of the recovery. At each of these cycle's scale, mechanical indicators were calculated at three levels of analysis that were individual, interpersonal, and boat levels respectively.

For the individual level of analysis the following indicators were computed: (a) the mean of force's values, based on rowers' force values captured at each instant on the pin of each oar lock in the direction of the longitudinal axis of the boat (N), (b) the standard deviation of these force's values (N), (c) the linear momentum of the force's values ($kg\cdot m\cdot s^{-1}$), (d) the peak force (N) for each stroke, (e) the peak force timing, defined as the specific moment within the cycle at which the maximum force's value occurred, expressed in percentage of the considered cycle (% of the cycle), (f) the range of motion of the rowers (°) captured at each instant in the horizontal plane, computed as the difference between the catch angle and the angle at which the oar leaves the water. Then, from the instantaneous values of angular velocity of the oar (i.e., computed as the first derivative of the angular position, using the central difference formula), we computed for each cycle: (g) the mean of the angular velocity of the oar ($°\cdot s^{-1}$), and (h) the mean of the strokes' variability regarding angular velocity, computed from the standard deviation's values obtained on each cycle ($°\cdot s^{-1}$).

At the interpersonal level of analysis, synchronization of oar angles and of peaks force were scrutinized. Regarding oar angles synchronization, the Continuous Relative Phase (CRP) between the stroke rower and the bow rower was selected (de Brouwer, de Poel, & Hofmijster, 2013; de Poel, de Brouwer, & Cuijpers, 2016; Seifert, Adé, Saury, Bourbousson, & Thouvarecq, 2016) and was calculated according to Hamill, McDermott, and Haddad (2000). 101 CRP data points (i.e., 0–100% of the cycle) were thus obtained for each cycle regarding angle. It led to the following indicators to be retained for each cycle: (a) the mean of the angle's CRP (°), (b) the mean of the stroke's variability regarding the angle's CRP, computed from the standard deviation's values obtained on each cycle. We also calculated for each cycle (c) the difference between the catch angle's timing of the stroke and the bow rower, respectively (%). Regarding peaks force synchronization, we calculated: (d) the gap (i.e., captured as a difference) between each individual peak force level (N), and (e) the gap (i.e., captured as a difference) between the timing of each individual peak force (%).

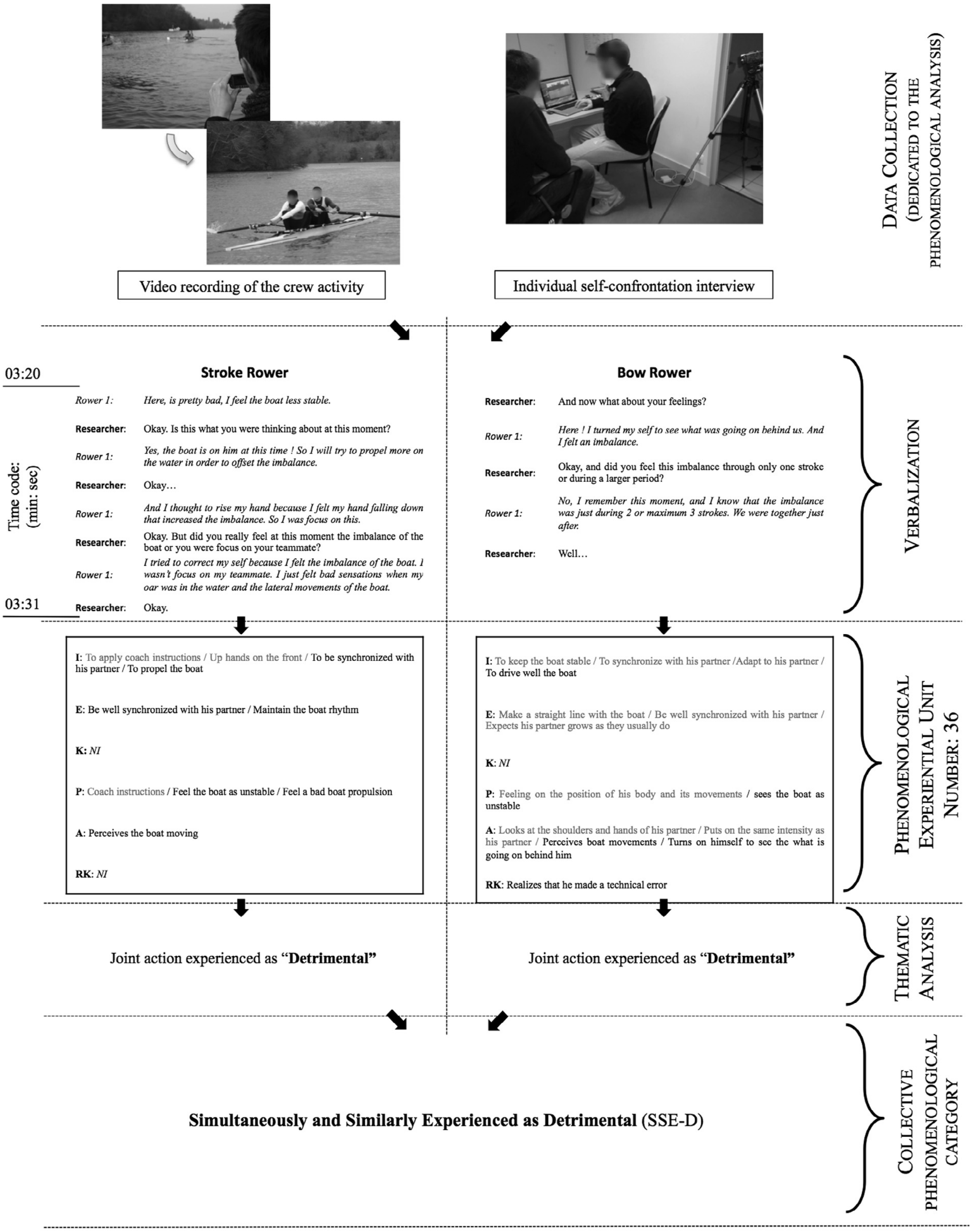
At the boat level of analysis the following indicators were retained for each cycle (a) the mean of the boat's velocity ($m\cdot s^{-1}$) and (b) the mean of the boat's acceleration ($m\cdot s^{-2}$).

2.3.3. Subjectivity-based sampling method: Identifying the mechanical signatures related to the typical experiences of joint action

Mechanical samples of data were built through a subjectivity-based sampling method. This procedure involved first scrutinizing the phenomenological data (i.e., the rowers' course-of-experience) to delineate the samples of behavioral data to be compared (i.e., various ways of experiencing the strokes give rise to various delineated sections within the race that will be further processed/compared). Such a subjectivity-based sampling method has been well developed in enactivist neuroscience (e.g., Froese, Iizuka, & Ikegami, 2014a,b; Lutz, Lachaux, Martinerie, & Varela, 2002; Lutz & Thompson, 2003; Rodriguez et al., 1999). The principle is to guide the observational study (e.g., brain dynamics observation, behavioral dynamics observation) using phenomenological data collected during the same task. This procedure includes the human pre-reflective experience as a valuable facet of the activity under study and then investigates the correlated observational (i.e., behavioral) measures that support its occurrence. Based on the qualitative analysis, four collective phenomenological categories were identified: the SSE-M (i.e., Simultaneously and Similarly Experienced as Meaningless), the SSE-D (i.e., Simultaneously and Similarly Experienced as Detrimental), the SSE-E (i.e., Simultaneously and Similarly Experienced as Effective), and the SDE (i.e., Simultaneously Diverging Experiences), respectively. Then, the procedure involves delineating boundaries of mechanical samples from the course-of-experience of the rowers (see Fig. 2). To this end, the time code at which each typical experience occurred was recorded to identify all intervals falling under the same typical experience and the associated mechanical data were subsequently aggregated in corresponding samples. Various samples of mechanical data were thus obtained using this procedure, each of them assumed to reflect different ways of experiencing the joint action, that were the four collective phenomenological categories (e.g., SSE-M, SSE-D, SSE-E and SDE; see results section).

2.3.4. Statistical analysis

Statistical analysis was carried out on the mechanical properties of each of the four samples using the SPSS 17.0 statistical software package (SPSS®, Inc., Chicago, IL, USA). Descriptive statistics are reported using the mean and the standard deviation (mean ± SD). Differences between the four categories regarding each mechanical indicator were analyzed using multiple analysis of



Stroke Rower

Rower 1: *Here, is pretty bad, I feel the boat less stable.*

Researcher: Okay. Is this what you were thinking about at this moment?

Rower 1: *Yes, the boat is on him at this time ! So I will try to propel more on the water in order to offset the imbalance.*

Researcher: Okay…

Rower 1: *And I thought to rise my hand because I felt my hand falling down that increased the imbalance. So I was focus on this.*

Researcher: Okay. But did you really feel at this moment the imbalance of the boat or you were focus on your teammate?

Rower 1: *I tried to correct my self because I felt the imbalance of the boat. I wasn't focus on my teammate. I just felt bad sensations when my oar was in the water and the lateral movements of the boat.*

Researcher: Okay.

Bow Rower

Researcher: And now what about your feelings?

Rower 1: *Here ! I turned my self to see what was going on behind us. And I felt an imbalance.*

Researcher: Okay, and did you feel this imbalance through only one stroke or during a larger period?

Rower 1: *No, I remember this moment, and I know that the imbalance was just during 2 or maximum 3 strokes. We were together just after.*

Researcher: Well…

I: To apply coach instructions / Up hands on the front / To be synchronized with his partner / To propel the boat

E: Be well synchronized with his partner / Maintain the boat rhythm

K: *NI*

P: Coach instructions / Feel the boat as unstable / Feel a bad boat propulsion

A: Perceives the boat moving

RK: *NI*

I: To keep the boat stable / To synchronize with his partner /Adapt to his partner / To drive well the boat

E: Make a straight line with the boat / Be well synchronized with his partner / Expects his partner grows as they usually do

K: *NI*

P: Feeling on the position of his body and its movements / sees the boat as unstable

A: Looks at the shoulders and hands of his partner / Puts on the same intensity as his partner / Perceives boat movements / Turns on himself to see the what is going on behind him

RK: Realizes that he made a technical error

Joint action experienced as "**Detrimental**"

Joint action experienced as "**Detrimental**"

Simultaneously and Similarly Experienced as Detrimental (SSE-D)

Note: I= Involvement in the situation, E= Expectations, K= prior mobilized Knowledge, P= Perception, A= Action, RK= Refashioned Knowledge

Fig. 2. Illustration of how the collective phenomenological categories were obtained. At the step of identifying the components of the phenomenological experiential units, words in grey are components that remain active at the considered instant, but which were delineated through front units to the current unit of experience. Words in black highlight the components that were especially identified through the present verbalizations.

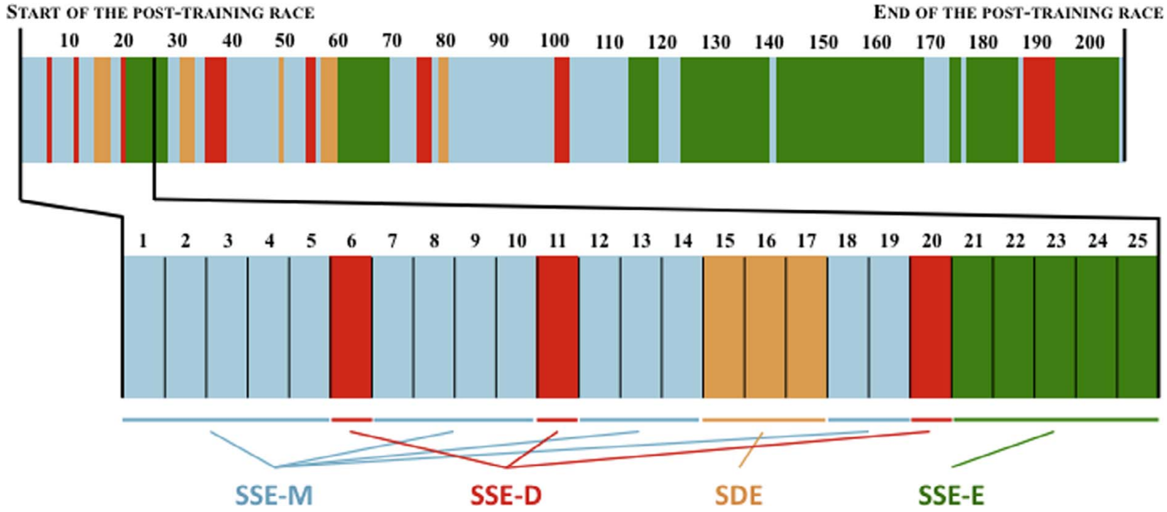


Fig. 3. Repartition of the lived experiences throughout the race, as obtained from a collective level of analysis. *Note*: SSE-M, Joint action Simultaneously and Similarly Experienced as Meaningless; SSE-D, Joint action Simultaneously and Similarly Experienced as Detrimental; SSE-E, Joint action Simultaneously and Similarly Experienced as Effective; SDE, Simultaneously Diverging Experiences of joint action.

variance (two-way ANOVAs) for the individual level of analysis and Kruskal-Wallis (K-W) tests for the interpersonal and boat level of analysis for each part of the cycle, in line with the statistical analyses performed in the initial study. False Discovery Rate (FDR) controlling procedure across all the ANOVA/K-W condition main effects was performed according to Benjamini and Hochberg (1995). Such a procedure was assumed to reduce/avoid type I error. As preconized by the authors (Benjamini & Hochberg, 1995) we sorted all the p-values ($N = 70$) in ascending order and considered that a fraction $q = 0.05$ of discoveries are tolerated to be false. We denoted $H_{(i)}$ the hypothesis corresponding to $p(i)$. Let k be the largest i for which $p(\mathrm{i}) \leqslant \frac{i}{N}q$. Then we rejected all the null hypotheses as $H_{(i)}$, $i = 1,2,\ldots, k$.

From the FDR procedure applied to ANOVA and K-W tests, only effects shown to be significant after this procedure were retained for following post hoc analyses. For the ANOVAs, Tukey's HSD post hoc were applied to the data sets (SSE-M, SSE-D, SSE-E and SDE), with the rowers for the individual level (Rower 1 and Rower 2), as independent variables and the mechanical indicators listed above as dependent variables. When significant effects were revealed through the K-W tests, Dunn's tests were performed as Post hoc analyses, and allowed to identify the location of differences between categories (Dunn, 1961). Residuals were checked carefully for normal distribution using QQ plots. For all tests, the level of significance was fixed at $p < 0.05$.

3. Results

3.1. Proportion of strokes related to each collective phenomenological data

The phenomenological data analysis showed that the strokes in which joint action was simultaneously and similarly experienced as "meaningless" by the participants (i.e., SSE-M sample) accounted for 39.2% of the race ($N = 82$ strokes out of 209 strokes). The strokes in which joint action was simultaneously and similarly experienced by the participants as "detrimental" (i.e., SSE-D sample) accounted for 10% of the race's period ($N = 21$ strokes). The strokes in which joint action was simultaneously and similarly experienced by the participants as "effective" (i.e., SSE-E) accounted for 45% of the race ($N = 94$ strokes). The strokes related to simultaneous diverging experiences of the rowers (i.e., SDE sample) accounted for 5.8% of the race ($N = 12$ strokes). Fig. 3 illustrates these results.

3.2. Comparison of the four mechanical samples at three levels of analysis

The mechanical data associated with the four identified collective phenomenological categories (SSE-M, SSE-D, SSE-E, and SDE) were then submitted to further statistical analysis. The analyses aimed at identifying the level of joint action's organization (i.e., individual, interpersonal, or boat level) that could best explain the mechanical differences in the four collective phenomenological categories.

Using the FDR controlling procedure with $q = 0.05$, we compared sequentially each $p_{(i)}$ with $0.05i/70$, starting with $p_{(70)}$. The first p-value to satisfy the constraint was $p_{(3)}$ as $p(3) = 0.0012 \leqslant \frac{3}{70}0.05 = 0.0021$. The null hypotheses having p-values less than or equal to 0.0021 were rejected.

3.2.1. Individual level of analysis

At the individual level of analysis, no significant difference between mechanical samples was found on any indicator (see Supplementary Tables 1–3).

3.2.2. Interpersonal level of analysis

At the interpersonal level of analysis, the K-W test pointed out a main effect of the collective phenomenological categories on the angle's continuous relative phase during both the first ($H_{(3)} = 27.633$; $p = 0.0001$) and the second half of the recovery ($H_{(3)} = 20.274$; $p = 0.0012$). The FDR controlling procedure rejected the null hypothesis for p values equal or under the threshold of $p = 0.0021$, what led us to confirm the given effects. For the first half of the recovery, the Dunn's test revealed a significant difference between SDE and SSE-E ($p < 0.001$) on the angle's continuous relative phase. For the second half of the recovery, the Dunn's test revealed a significant difference between SDE and SSE-D ($p < 0.001$) on the angle's continuous relative phase. Thus, the angle's continuous relative phase was significantly closer to 0° (i.e., in phase) in the SDE sample in comparison to the SSE-E sample, as captured during the first part of the recovery (Mean $_{\text{SDE}}$ angle CRP = $-7.70° \pm 12.17°$ *versus* Mean $_{\text{SSE-E}}$ angle CRP = $-11.16° \pm 14.40°$). The SDE sample also exhibited CRP values closer to 0° when compared to the SSE-D sample, as captured during the second part of the recovery (Mean $_{\text{SDE}}$ angle CRP = $1.38° \pm 22.45°$ *versus* Mean $_{\text{SSE-D}}$ angle CRP = $-15.03° \pm 38.09°$; see Supplementary Table 4).

3.2.3. Boat level of analysis

At the boat level of analysis, Kruskal-Wallis test was confirmed by the FDR controlling procedure, pointing out an effect of collective phenomenological category on the boat velocity ($H_{(3)} = 16.507$; p-value = 0.001). The Dunn's test revealed a significant difference between SSE-D and SSE-E ($p = 0.001$). Boat velocity was significantly higher in the SSE-D sample than in the SSE-E sample during the first part of the drive (Mean $_{\text{SSE-D}}$ boat velocity = $2.28\ \text{m·s}^{-1} \pm 0.06\ \text{m·s}^{-1}$ *versus* Mean $_{\text{SSE-E}}$ boat velocity = $2.21\ \text{m·s}^{-1} \pm 0.06\ \text{m·s}^{-1}$; See Fig. 4 and Supplementary Table 5).

4. Discussion

Being a follow-up case report grounded on the initial case study from R'kiouak et al. (2016) that analyzed how two individual experts rowed together while never having practiced together before. The present investigation seized the opportunity to investigate how the same two rowers synchronized after having intensively practiced joint action through a national training program in which they were invited to take part. Our scientific goal was to track likely changes in the inter- *versus* extra-personal modes of co-regulation within the activity of the given rowers (e.g., a change in the proportion of the race in which joint action was meaningless). To this end, a phenomenological analysis allowed to first scrutinize the extent to which the rowers simultaneously and similarly experienced joint action as being salient. Then the underlying modes of co-regulation were inferred from the mechanical properties that were the best candidates to explain differences between the joint sense-making modalities.

To recap, the initial study findings (R'kiouak et al., 2016) highlighted that co-regulating the crew's joint action could be either meaningful (e.g., suggesting an active co-regulation of joint action) and/or meaningless (e.g., being probably more grounded in spontaneous mutual motor entrainment). In the details, the authors pointed out that: (a) For 75.5% of the oar strokes both rowers did not pay attention to their joint action, at the level of the pre-reflective experience of their activity (i.e., SSE-M), what the authors characterized as being meaningless to the interactors; (b) 16.2% of the oar strokes were similarly and simultaneously experienced as a salient, meaningful experience of either detrimental joint action (7.4%) (SSE-D) or effective one (8.8%) (SSE-E); (c) the mechanical index that was proposed to correlate the collective phenomenological categories of a detrimental (SSE-D) or an effective (SSE-E) joint action was the differential peak force level of the rowers. This result led the authors to suggest that the salient, meaningful experience of effectiveness exhibited by both rowers were likely rooted in the interpersonal level of organization. Authors then interpreted this result as a meaningful inter-personal mode of co-regulation of their joint action. As we aimed to compare the present results with the initial ones, we further re-processed the initial mechanical data to be in accordance with the present analyzes (i.e., applying a FDR

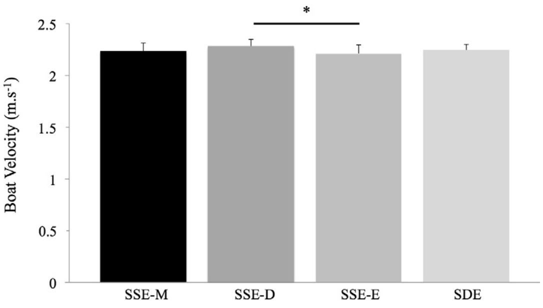


Fig. 4. Mean values and standard deviations of the boat velocity in each collective phenomenological category during the first part of the drive phase. *Note*: SSE-M, Joint action Simultaneously and Similarly Experienced as Meaningless; SSE-D, Joint action Simultaneously and Similarly Experienced as Detrimental; SSE-E, Joint action Simultaneously and Similarly Experienced as Effective; SDE, Simultaneously Diverging Experiences of joint action. Statistical significance was set to $P < 0.05$.

controlling procedure). Initial results were all confirmed (i.e., only one main effect of the collective phenomenological category on the differential of the peak force level of the rowers was found). No conclusion of the initial study required to be discussed again, thus inviting to compare the present results with the previous ones.

Obtained from on a similar design, the findings of the present follow-up case study were considered reflecting more skillful modes of co-regulation due to intensive team training (post-program race) and were expected to differ from those obtained in the initial study (pre-program race). More specifically, we expected rowers performing joint action in a ubiquitous extra-personal mode of co-regulation (i.e., when joint action is meaningful or/and meaningless to them), as observed through an increasing proportion of the race in which joint action was meaningless, and mechanical correlates of effectiveness experiences being rather found within boat-level indicators.

Regarding the qualitative analysis, the present study showed that both rowers simultaneously and similarly experienced joint action during the post-program race for 55% of their activity (i.e., merging SSE-M, SSE-E, and SSE-D samples), whereas a proportion of just 16.2% was observed at the pre-program race (R'kiouak et al., 2016). This result indicates an increase of the shared salient experiences within the given crew and suggests that shared salient experiences were more pronounced after both rowers extensively practiced together. This finding is notable in that we expected that rowers would increased the proportion of activity in which joint action was "meaningless" during the post-program race, which was not found here. On the contrary, practicing crew functioning was apparently associated with both individual expert rowers making more shared experiences of joint action. Regarding the present results, future research should further investigate how, why and when team practicing might contribute to reduce the background in which joint action was meaningless, while this mode was hypothesized to allow them to synchronize effortless when rowing together for the first time during the pre-program race. However, while being unexpected with regards to expertise in rowing, this finding might be in accordance with the hypothesis proposed by Froese and Di Paolo (2011). According to these authors, real-time shared awareness of joint action depends on the dynamics of co-regulation implied in the joint movement from which it emerges so that it might be enhanced over time when teammates increase the amount of shared interaction, that is when teammates engage in repetitive shared practice (Froese et al., 2014a,b). By merging the present results from the post-program race with those of the initial pre-program race, Fig. 5 highlights how rowers' shared salient experiences of effective/detrimental joint action evolved after training, illustrating how the amount of joint action shared awareness seemingly increased after the singular team training studied.

In the present study, mechanical analyses applied to the data related to each of the collective phenomenological categories pointed out a main effect of the collective phenomenological categories on angle's continuous relative phase during the first and the second half of the recovery, respectively. The observed differences were between the simultaneous diverging experiences (SDE) and (a) the simultaneous and similar experiences of an effective joint action (SSE-E) during the first part of the recovery phase, and (b) the simultaneous and similar experiences of a detrimental joint action (SSE-D) during the second part of the recovery phase. These results

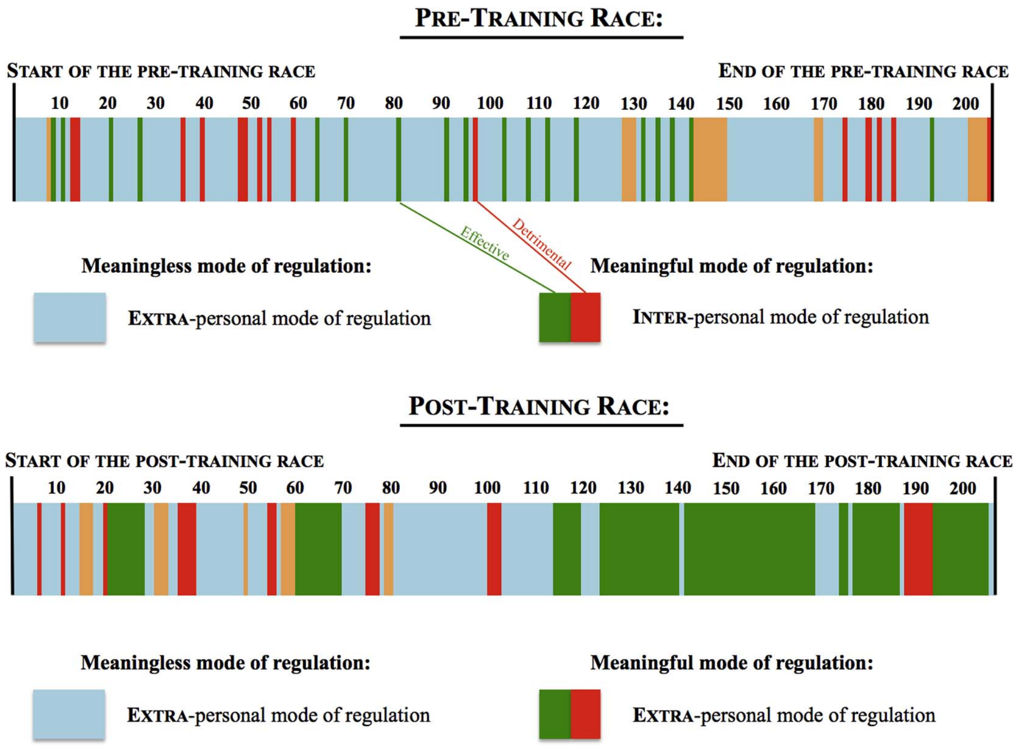


Fig. 5. Evolution of the collective phenomenological categories and the related modes of co-regulation across the period training.

mean that simultaneous diverging experiences of rowers were associated with a more locked angle's CRP, unlike what was observed when rowers similarly experienced their joint action as effective or detrimental. Higher phase locking during the recovery phase could be suggested to sign coordination patterns making it hard for rowers to be on the same page. In light of our hypotheses, the comparison between SSE-E and SSE-D allowed to suggest at which level of organization do the mechanical correlates of rowers' sense of effectiveness rely. In this regard, while the results of the pre-program race pointed out that the differential of the peak force level (i.e., captured at an inter-personal level of analysis) was the best index to explain differences between strokes experienced as effective versus detrimental, none of the retained inter-personal mechanical indices explained differences between the SSE-E and the SSE-D sample in the post-program race analyzed here. Instead, the shared meaningful experience of an effective joint action (SSE-E) could be distinguished from the detrimental one (SSE-D) with regards to the boat velocity values (i.e., captured during the first part of the drive phase of the oarlock) being lower in the SSE-E than in the SSE-D sample. Also, no significant difference was found between the collective phenomenological categories with regards for boat velocity values when considering the whole cycle. In the detail, strokes experienced here as detrimental started with a higher boat velocity, probably explaining the nature of their lived experience when both rowers did not succeed in maintaining further such velocity through full oar stroke. Thus, the results suggest that the meaningful experience of oar stroke's effectiveness was probably grounded in the ability of rowers to create and maintain a high boat velocity at the scale of the full cycle, making the task harder when the oar stroke started with a high velocity. Of note is that these results should be considered with caution since the number of oar stroke included in each sample (i.e., reflecting the phenomenological categories) changed from the pre-program to post-program race, what might have affect our capability of observing differences.

Our study thus suggests that the proposed explicative factors of the salient shared experience of the rowers' activity might be found at the boat level of analysis after training, whereas no significant insights were observed at this level of analysis during the pre-program race. Present results thus propose that the processes underlying rowers' meaningful mode of co-regulation probably changed through training. They also invite to consider that rowers' salient shared experience of effectiveness during the post-program race was, at least in part, rooted in the dynamical variations of the boat velocity, thus implying a meaningful extra-personal mode of co-regulation of their joint action after shared practice.

The switch suggested in this case study, from inter- to extra-personal co-regulation processes of coordination, might question how current research takes into account the mediating role of the environment in shaping joint action of social systems. Indeed, in the research, actors have been considered as the principal components of the systems under study, which led scholars to investigate how intra-team patterns were shaped by individual activities or by the nature of the dynamical ongoing interactions (see Araujo & Bourbousson, 2016 for details on the current available frameworks). Having focused on the intra-team cognition or behavior that emerges from interactions between actors, previous researches are scarce that have considered how the environment/context may be a background that helps to better explain how humans achieve joint action in complex and uncertain environments (see Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007 for an exception, but dedicated to the study of spontaneous collective behavior). Actually, most of the experimental studies that examined factors enabling participants' active behavioral synchronization have assumed an inter-personal mode of co-regulation, such that the role of the environment as a medium was voluntarily removed from study (Avitabile, Słowiński, Bardy, & Tsaneva-Atanasova, 2016; Marsh, Richardson, & Schmidt, 2009). As it is assumed in the various actor-environment coupling theories (Kelso, 2001; Varela, Thompson, & Rosch, 1991), the environment is considered as a very constitutive part of the behavioral system. However, in our opinion, research could better describe how this claim works and helps to understand human activity. However, while adopting another approach, Lippens (1999, 2005) suggested a model of direct and indirect interaction in rowing where the indirect interaction of the synchronization performance somewhat reflects what we call an extra-personal process of coordination. Indeed, Lippens described how the optimal run of the boat seems to be controlled by both rowers in special individual interaction with the environment: e.g., the stroke rower controls the lateral movements of the stern and the bow rower controls the stability of the stroke by using auditory reafferences. The present study thus might contribute to such a description, and illustrates how the interpersonal mediating function of material environment can be further considered in future research.

However, some studies can be found that emphasized the environment's role in human social systems and thus provided a theoretical background for extra-personal co-regulation processes. Such research relates to the field of cooperative work, for example, where authors have applied the concept of *stigmergy* to human practices (Christensen, 2008, 2013; Marsh & Onof, 2008; Parunak, 2005; Susi, 2016; Susi & Ziemke, 2001). To illustrate, stigmergic processes have been invoked to account for cases in which "*actors may coordinate and integrate their cooperative efforts by acting directly on the physical traces of work [previously] accomplished by others (or themselves)*" (Christensen, 2013, p. 40). Of note is that most of these works were conducted on collectives that were quite large and in which tasks were distributed in space and time, thus making the environment a clear catalyst for team behavior. In comparison, sports settings call for real-time and co-located multi-actors' coordination. In light of this literature and the present exploratory case study, lines of research on stigmergic processes in sport might be fruitfully opened, and rowing crew behavior being probably a heuristic study setting in this light. However, because the rowing task goal is to enhance/maintain the boat velocity and synchronization being only a mean to achieve it, the question remains open to know whether a change from inter- towards extra-personal mode of co-regulation would also occur in performance settings where synchronization is the task goal.

There are limitations to this study. In terms of the internal validity, the cyclical repetitive movements of rowing may question the capability of the rowers to adequately comment their activity and exactly remember each stroke during the retrospective interview. While this question remains open, rowers' accounts of their lived experiences were carefully checked regarding the video recording, the available mechanical data, and through a comprehensive verification of the consistency/relevance of what was commented by the participant. Aspects of this study also limit the generalizability of the findings because the study involved relatively small data sets, and only one crew was investigated, suggesting that the present results can be mainly transposed to other cases exhibiting similar characteristics (e.g., crew experience, stroke-rate). Moreover, measures of phenomena occurring at the interpersonal level of rowing should be further developed, especially regarding criticisms about the use of average CRP, as recently made by Feigean and colleagues (2017) in their study of interpersonal coordination patterns in rowing. Finally, and to reiterate methodological limitations raised above, the subjectivity-based sampling method adopted here generated a difference in the number of cycles included in each sample that could have affect the results. Again, while the FDR controlling procedure was used, the very large number of ANOVAs/Kruskal-Wallis tests performed (N = 70) minimized the risk of having type I error.

5. Conclusions and perspectives

The subjectivity-based sampling method used here is relatively new to sports science (R'kiouak et al., 2016). In our opinion, such a method might be a promising way to sample and process performance indicators. At a time when many digital tools are available to practitioners to track every movement of the athlete (e.g., GPS devices in team sports) (Memmert, Lemmink, & Sampaio, 2016), such a method provides guidelines to investigate how the movement patterns can change through the unfolding activity, and to consider that key patterns can be identified through the use of athletes' phenomenological experiences (Seifert et al., 2016; Sève et al., 2013).

In the specific field of joint action research, two main issues can be retained: (a) the modes of co-regulation underlying a social system functioning probably change through practice, what might help to explain how a team becomes expert. Our opinion is that future research should empirically describe/discover these modes in various social systems, rather than presuppose them within the theoretical framework or the experimental design; (b) since the modes of co-regulation might change through training, future research should address how environmental constraints allow for a given mode of co-regulation to be more viable and prominent in the various settings and levels of practice of a sport. In the specific case of rowing, it could be of interest to investigate whether increasing stroke rate would be able to change such coordination processes, as suggested by some authors in the rowing literature (Cuijpers et al., 2016). Moreover, sport psychology could question whether specific kind of phenomenological experiences are facilitated/prevented by the emergence of extra-personal processes of coordination. For instance, researchers might investigate whether the well-known capability of athletes to get into the "zone" (also called flow experience) is likely to occur as joint action becomes meaningless to the athlete, like when focalizing on the material situational mediation of the boat implied in a rowing crew behavior.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.humov.2017.09.008.

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ÉTUDE 3

TEAM SYNERGIES IN ROWING: HOW ACTIVE CO-REGULATION OF A COXLESS PAIR CREW CHANGED UNDER THE EFFECT OF DIFFERENT CADENCES

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Team synergies in rowing: How active co-regulation of a coxless pair crew changed under the effect of different cadences

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Abstract:

While « Team synergies » have been introduced as a main topic for understanding the emergence of collective behaviors in sport (Araujo & Davids, 2016), no study has investigated the processes of « active co-regulation » between team members movements in a naturalistic joint action task. The purpose of the present case study was, to characterize such active co-regulation process in rowing, and to look at the effect of rowing cadence in changing such a process.

The behaviors of an expert female coxless-pair crew were tracked through four races with different cadences: 18 strokes per minute (C1), 24 strokes per minute (C2), 28 strokes per minute (C3) and 36.5 strokes per minute (C 4). The behavioral measures were collected with the Powerline system. An adapted version of the uncontrolled manifold was applied, on the angle phase of both rowers during the drive phase, to measure an indicator of reciprocal compensation for each condition (Latash, et al., 2002). Three different portions were delimited during the stroke cycle: entry, drive and release. Hierarchical clustering was used in order to show the similarities/dissimilarities between the periods of each condition. Behavioral data was complemented with verbalization data (R'Kiouak et al., 2016) in order to describe what participants perceive, and how they actively regulate their interpersonal states within each condition. This verbalization data was processed through a qualitative thematic analysis (Braun & Clark, 2006).

The mechanical results pointed out (1) the entry looks similar for the high cadences (cluster 1= C1; cluster 2= C2, C3 and C4), (2) the drive looks dissimilar between the low and the high cadences (cluster 1= C1 and C2; cluster 2= C3 and C4), and (3) the release looks similar for the low cadence (cluster 1= C1, C2 and C3; cluster 2= C4). The phenomenological data pointed out that the experiences of the rowers are really detailed concerning the entry and release periods but rowers never talked about the drive.

Thus, the rowers changed their Leader-Follower (L-F) relationship under different cadences as an adaptation to maintain boat efficiency. Moreover, the individuals' behavioral mutual adjustments allowed rowers to maintain the stability of the continuous relative phase between their respective strokes, signing the presence of degeneracy in the rowers' social system. Finally, increases in rowers' participatory sense-making accompanied the increase in behavioral mutual adjustment.

Introduction

Social synchrony has often been explained in terms of physical interaction phenomena, such as simple pendulums clocks synchronizing their oscillations through the vibrations that they provoked and shared on the wall (Winfree, 2001) or in biology when a species of firefly synchronized their individual flashing (Buck & Buck, 1976). Synchronization between agents is not always perfect, and often exhibits functional variability. For example, based on Von Holst (1973) initial work; Kelso (1995) pointed out that interpersonal coordination can be absolute (i.e., perfect level of synchrony) or relative (i.e., the actors are synchronized only transiently and then break apart). These forms of interpersonal coordination are not only a matter of motion but they could be explained as a kind of functional pattern that is flexibly adjusted to various constraints (Kelso, 2002) to keep a stable (or viable) collective state. Many works describe interpersonal coordination behaviors, i.e. their movements' statistical signatures, but few works have described how actors come to be coordinated and to dynamically manage the interpersonal coordination (see Bourbousson & Fortes-Bourbousson, 2016 for an opinion). This is the object of our study. To maintain and/or disrupt such synchronization, individuals regulate their behaviors with regards for what they perceive as the emerging needs of the interpersonal coordination. Thus, the behavioral management of the interpersonal coordination and how it is actively regulated by the actors (i.e., when it is meaningful to them) seems to be a promising way to better understand social interaction in the context of synchrony phenomenon.

The active (co-)regulation of the interpersonal coordination was mainly discussed in line with the so-called enactive approach. The enactive approach is a heuristic to apprehend the notion of social interaction (e.g., Araujo & Bourbousson, 2016; De Jaegher & Di Paolo, 2007; Froese & Di Paolo, 2011). First, this approach defines human activity as the product of a coupling between an actor and the environment. Moreover, the enactive approach postulates that the human activity results from an actor-environmental coupling being asymmetrical (i.e., the actor interacts only with the perturbations to which he is sensitive, and not the whole environment) such that it takes into account the actor's situated activity of sense making. In this way, the actor constructs his "own-world", i.e. the actor point of view (Varela, Thompson & Rosch, 1991) that emerged from specific interactions with the environment. Second, to understand the social interaction, the starting point was often behavioral, in the sense that the goal is to start the investigation from the observation of non-accidental behavioral correlations (e.g., Marsh, Richardson, & Schmidt, 2009; Alderisio, Fiore, Salesse, Bardy, & Bernardo, 2017). However, to be able to speak of social interaction in the enactive sense, it is necessary to give as a situation of study the cases in which the actors actively co-regulate their interpersonal states, that is meaningfully manage their non-accidental behavioral correlations.

More specifically, the notion of co-regulation, can be defined as the simultaneous commitment of all the actors' active regulation engaged in the collective activity. Towards this idea, De Jaegher and Di Paolo (2007) suggested that co-regulation is the essential element for a strong social interaction process. Co-regulation is therefore understood to mean the way in which the interpersonal coordination takes place in situations by simultaneous adaptations of the individuals concerned. The necessity of co-regulation was tested in several studies, as in Froese, Iizuka and Ikegami (2014a, 2014b), where participants were in a situation in which they move an avatar in a minimal virtual environment made of different entities (e.g., human avatar, moving lures and fixed lures). In this design, no visual information was available except the encounter of each of the entities, with the mouse being a unique type of tactile stimulation that makes the encounters undifferentiated. In other words, their meeting provides the same sensory information. The task for the participants was to recognize the presence of their partner and to indicate it by a mouse click. This manipulation allowed testing the respective contribution of the interaction process and the individual information in the emergence of a coordinated interaction. Results have shown that participants can recognize when the all-or-none tactile stimulation they experienced was attributable to a co-regulated encounter (i.e., when crossing the other participant's avatar) rather than a non-regulated encounter (i.e., crossing the mobile of fixed object). Furthermore, participants were shown to mutually managed to find each other when the agent with whom they co-ordinate was also actively adjusting his activity. Thus, the co-regulation could allow the subject to experience social interaction in a more powerful way, particularly in enhancing the meaningful experience of the actors implied in such a process of interaction.

As the phenomenological level of activity was shown to be very implied, the active regulation of the social interaction cannot be fully understood by the physical notion of interpersonal coordination as it was previously defined. Phenomenology of actors was thus considered an important piece of the puzzle to understand the co-regulation process, and has to be measured in order to understand the actor point of view (i.e., own world) and to advise the information that allows her/him to regulate her/his interactive motor action. As a consequence, the active co-regulation was apprehended a lot from an exclusive phenomenological approach (e.g., Bourbousson, R'Kiouak & Eccles, 2015; Lund, Ravn Christensen, 2012, 2013; Poizat, Bourbousson, Saury & Sève, 2009), without any specific tools apprehending the behavioral reality (i.e., behavioral co-regulation, behavioral mutual adjustments) (See Araujo & Bourbousson, 2016, for a review).

Here we try to describe this co-regulation of joint action, by combining behavioral indices as described from third person tools (i.e., mechanical), with the phenomenological correlates as obtained from first-person descriptions. Together, these elements should make it possible to propose a fully enactive approach of co-regulation, in the way it contributes to building a perfect synchony, under the effect of constraints forcing the system to reorganize.

In this way, in order to empirically capture the active co-regulation (i.e., the behavioral interpersonal adjustments and the lived experiences associated), studies would benefit from articulating behavioral data and the phenomenological data. Indeed, some studies in sports attempted to articulate the behavioral data and the phenomenological activities of rowers (R'Kiouak, Saury, Durand & Bourbousson, 2016, *In press*; Seifert, Lardy, Bourbousson, Adé, Nordez, Thouvarecq & Saury, 2017). R'Kiouak and colleagues (2016) aimed to understand how a single pair of rowers co-regulate their interpersonal coordination by associating methodologically their lived experiences and their behaviors. The authors pointed out that the two rowers did not pay attention to their joint action during most of the race, however some cycles were simultaneously lived as a salient, meaningful experience of either a detrimental or an effective joint action, and the mechanical signatures diverged across the delineated phenomenological categories, suggesting that the way in which the cycles were experienced emerged from the variance in some mechanical parameters. They concluded that attempts to combine phenomenological and mechanical data should be pursued to continue the research on how individuals regulate the effectiveness of their joint action dynamics. Even if this interdisciplinary study worked on the active co-regulation, they placed the focus on the "what" to explain the similarity of judgment of a good or bad oar stroke. However, no studies have investigated the active co-regulation by searching behavioral mutual adjustments and how they are meaningfully regulated to different constraints during an ecological situation.

In this study, we hypothesized that (1) the amounts of behavioral mutual adjustments, as captured by behavioral measures, were related to different lived experiences during an ecological collective activity and (2) the actors were capable of adapting their active co-regulation to different constraints, as captured from both behavioral and phenomenological descriptions. To achieve these objectives, a sweep-oar coxless-pair crew in rowing was selected. In sweep-oar rowing, each rower operates a single oar (either on the left or on the right) and a sweep-oar coxless-pair the crew is made of two rowers, with the bow rower being closest to the bow and the stroke rower being closest to the stern. Indeed, this boat requires interpersonal coordination in order to propel and maintain the boat velocity, and to stabilize the boat. Thus, rowers have to actively co-regulate their activities. Moreover, rowing seems to be particularly interesting to observe changes at the team scale (Feigean, R'Kiouak, Bootsma & Bourbousson, 2017), especially when implying different range of stroke rate (Cuijpers, Passos, Murgia, Hoogerheide, Lemmink & de Poel, 2016). Concerning, the phenomenological part, studies have shown that rowers were capable of providing detailed accounts of how they experienced their coordination in a real situation (i.e,. R'Kiouak et al., 2016, *In press*; Seifert et al., 2016, 2017; Sève, Nordez, Poizat & Saury, 2013). In the present work, rowing was considered a powerful study setting to investigate co-regulation of interpersonal coordination states, as captured by both behavioral and phenomenological descriptions.

Method

Participants and procedure

A crew composed of two female rowers (age: 20 years) participated in this study. Both were expert in terms of collective practice: they rowed together for 5 years in coxless pair crew rowing, and they participated 2 years in a row at the French championship final. Four sessions were organized, each of them imposing a specific cadence condition: 18spm-session (stroke per minute), 24spm-session, 28spm-session and 36.5spm-session. These cadences were selected because rowers had a previous large amount of practice at these stroke rates. Indeed, the first three cadences are fixed by the French national federation as optimal cadence to use during training, and the last cadence (i.e., 36.5) is the maximal cadence that the rowers were able to perform (i.e., reflecting the cadence produced in competition). Each session was composed of 65 oar strokes, with at least 15 minutes of rest between sessions. Rowers were always asked to perform at maximal power during every stroke. The four sessions unfolded in calm and very similar weather conditions.

This study was performed in accordance with the Declaration of Helsinki and the APA ethics guideline. A local Institutional Review Board of the university approved it. The two rowers and their coaches were informed of the procedures. The participants provided written informed consent.

Data Collection

Two distinct kinds of data were collected to account for the activity of the two rowers during each of the sessions: mechanical data was recovered and phenomenological data. Combined, these data account for how rowers adjust their movements to each other.

Mechanical Data Collection

During each session, mechanical data was collected using an automatic mechanical device, called the *Powerline* system (Peach Innovations, Cambridge, UK). This system is composed of different sensors that are directly fixed on the boat (i.e., angular sensors on each oarlock and an accelerometer fixed under the shell). Thus, the system allows collecting the mechanical data on the water and in a performance context. Two mechanical measures were captured at 50Hz (Coker, Hume and Nolte, 2009): the horizontal gate oar angle performed by each rower (°), and the boat velocity ($m.s^{-1}$). Powerline angle sensors provide an accuracy of 0.5° (Coker, 2010). The 5 first oar strokes were removed, corresponding to the « *launch of the boat* ». Each oar cycle was considered in two sections: the drive and the recovery section. The drive section takes place in the water; during this section the boat is powered. The drive begins with the catch (i.e., with a minimum oar angle) and ends with the finish (i.e., with a maximum angle) (R'Kiouak et al., 2016, *In press*; Seifert et al., 2017). The recovery section of a stroke takes place out of the water. As the rowers did not exhibit stable signatures out of water, particularly at 18 strokes per minutes (i.e., due to balance), we focused on the drive only. All the treatments were carried out from the horizontal gate oar's angle position (i.e., oar’s cycle) filtered with a low pass Butterworth filter, with a 6 Hz cutoff frequency. This function filters the original signal twice: in its original and reversed order to retain all phase information.

Phenomenological Data Collection

During each session, phenomenological data was collected using specific techniques of stimulated recall, called enactive interviews (Rochat, Hauw, Antonini Philippe, Crettaz von Roten & Seifert, 2017). Self-confrontation interviews allow for collecting data that accounts for how each rower lived his/her activity, at a pre-reflective level of subjective experience.

Pre-reflective self-consciousness characterizes the immediate experience that individuals make of their activity; that is, the *meaning* that emerges from their action at each instant and that supports how the course of the activity unfolds (Varela et al., 1991; Theureau, 2003). An individual can account for the meaningful part of each instant of his/her activity (i.e., he/she can *show it*, *tell it* and *comment on it*) under certain methodological conditions of interview that allows the athlete to re-enact the world in which he performed. According to the course-of-action methodology (Theureau, 2003), a self-confrontation interview invites a given actor to be confronted with behavioral traces of the activity he/she has just performed (e.g., audio-video recording). He/she is then helped to focus only on the immediate experience he/she had through specific questioning by the interviewer (Theureau, 2003). In the present study, the behavioral traces of rowers’ activity were produced with online audio recordings (both rowers were equipped with microphones) and video recordings (the sessions were filmed from a boat that followed the coxless pairs). Interviews were conducted immediately after each session. The lived experience that the actors accounted for concerned their perceptions (e.g., informational flows such as visual, kinesthetic, haptic, or acoustic constraints), concerns (e.g., purposes and intentions) and actions (e.g., communications between rowers, actions with the oar). By respecting the step-by-step unfolding of the activity, interviews allow the researcher to more fully focus on the dynamics of the individual's perceptions and concerns in the situation and the dynamics of what was meaningful for the individual at each instant. Researchers who had conducted self-confrontation interviews of this type in previous research conducted all the interviews. Each individual interview lasted around 45 minutes to 1 hour.

Data processing

Interpersonal Coordination Analysis

Mechanical data was processed first to characterize the continuous relative phase during the drive (i.e., CRP_{drive}). Second, we characterized the degree of behavioral mutual adjustments of the rowers (Latash, 2008; Latash, Scholz & Schöner, 2002).

First, continuous angular velocities were computed as the first derivative of the angular position using the central difference formula. Each stroke (i.e., cycle) was restricted to the drive section only (i.e., the first half of the cycle; Seifert et al., 2016, 2017). To allow for comparisons, each drive section was normalized to 51 points. In accordance with Hamill, McDermott and Haddad (2000), the data on angular displacements (θnorm) were normalized in the interval [-1, +1] and the angular velocities (ωnorm) were normalized in the interval [0, +1] for each drive section. Then, phase angles (φstroke and φbow, in degrees) were calculated and corrected according to their quadrant (Hamill et al., 2000). In line with de Poel, de Brouwer and Cuijpers (2016), interpersonal coordination can thus be characterized through the calculation of the continuous relative phase (φrel, in degrees) between the oar angles of the stroke and bow rowers, respectively (considered as two oscillators).

Then, inspired by studies in the field of motor control that aimed to characterize interlimb reciprocal compensation, we developed an adapted version of the uncontrolled manifold (UCM) (Scholz & Schöner, 1999, 2014), dedicated to the task of rowing teams. We applied this procedure on the phase angle of both rowers during the drive portion so that we created a ratio called R_V (i.e, Var_{UCM}/Var_{ORT}), which served as a reciprocal compensation index (see Latash, et al., 2002 for details), with respect to each portion of the drive section. Rv was calculated for each of the four data sets (i.e., sessions). Within a given cadence session, for every CRP_{drive} value (i.e., composed of 51 points), the ratio R_V was computed as the variance along the UCM (Var_{UCM}) on the variance perpendicular to the UCM (Var_{ORT}). For example, at the eleventh point of the drive section, the ratio R_V is equal to the variance of each eleventh point of all the oar strokes (i.e., that compose the cadence session) along the UCM divided by the variance of each eleventh point of each oar stroke perpendicular to the UCM (see Figure 1b). In this way all the points contributing to a particular R_V value were independent. The Var_{UCM} and Var_{ORT} were computed in a new matrix, created by a rotation plot, where the UCM was parallel to the abscissa line.

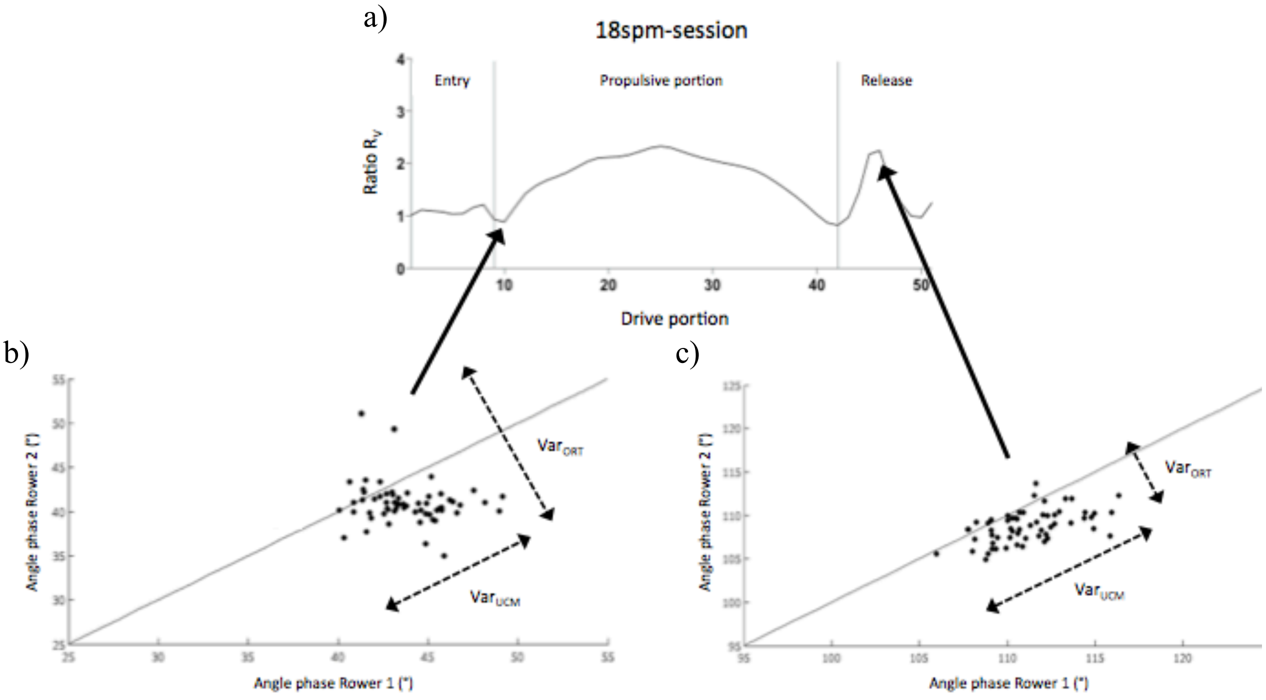

Figure 1: a) The Ratio R_V of the phase angle for the 18spm-session; b) An illustration of what a low value of the Ratio R_V means; c) An illustration of what a high value of the Ratio R_V means.

The UCM reflects a “control hypothesis” which is here the stabilization of the rowers’ coordination (i.e., a relative phase close to 0°) during the drive portion. Our implementation of UCM analysis takes into account the UCM hypothesis as Latash and colleagues (2002) or Riley and colleagues (Riley, Richardson, Shockley & Ramenzoni, 2011) have defined it (i.e., as a subspace of all possible coordinative relations for the task) and concentrates on 1:1 interpersonal synchronization between oar strokes as the control hypothesis. In this way, the method is able to show relations between variance components (i.e., the Ratio R_V) reflecting reciprocal compensation in maintaining relative phase close to zero and variance orthogonal to this control hypothesis. An improvement in performance (e.g., depending on the cadence condition) may be associated with an increase or a decrease of the R_V. Here, high values of R_V (i.e., high behavioral behavioral mutual adjustments) are comprised between 1 to 5 (see Figure 1a and Figure 1c) and low values of R_V (i.e., no behavioral behavioral mutual adjustments) are considered as less than 1 (see Figure 1b). Finally, our approach analyzes data clouds (e.g., phase angle) with respect to a particular performance variable (e.g., Relative phase) rather than components themselves. However, we assume that the control hypothesis (phase zero) is directly reflected in the relative phase measure that is analyzed.

From the Ratio R_V plots, three portions were further graphically delineated to account for the entry, the propulsive and the release portion of the drive (Coker et al., 2009), as performed by Feigean and colleagues (2017). The entry corresponded to the first 1/6 of the drive portion (i.e., the first 9 points), the propulsive portion corresponded to the next 4/6 of the drive portion (i.e., 33 points) and the release corresponded to the last 1/6 of the drive portion (i.e., the last 9 points) (see Figure 1a).

Phenomenological Analysis

The verbalization data from the self-confrontation interviews were processed according to the procedure defined in the course-of-action methodology (Theureau, 2003), which follows a comprehensive approach and is grounded in the enactive approach (Varela et al., 1991; Araujo & Bourbousson, 2016). We therefore followed six steps (see Seifert et al., 2017 for a similar procedure). First, we generated a table containing a brief description of each rower's activity as observed from the video recording and, in others columns, the verbatim transcriptions of the self-confrontation interview.

Second, we identified the elementary units of meaning (EUMs), which are the smallest units of activity that are meaningful for an individual. A given EUM lasts until another unit begins from the point of view of the actor; its duration thus depends on the intrinsic sense-making dynamics of the rower. To illustrate, in the present study, the delineated units were close to the duration of an individual oar stroke, suggesting the importance of each oar stroke in experiencing the session.

Third, we reconstructed each rower's personal course of action, leading to the identification of the perceptions and the concerns within each EUM that were meaningful to each rower. Therefore, the reconstructions of the rowers' courses of action consisted of identifying and documenting the components of the EUMs. Three components were identified and documented in this study: the *unit of course of action,* the *perceptions* and the *concerns*. The *unit of course of action* is the fraction of pre-reflective activity that can be shown, told, and commented on by the individual. The unit of course of action may be a symbolic construct, physical action, interpretation, or emotion. *Perception* corresponds to the elements that are taken into account by the individual at a given moment, without presaging that the rowers engage his/her activity towards this perception. C*oncerns* (i.e., involvement) refer to the inherent interest of the rower's current activity based on what is meaningful to him/her. In our study, we focused particularly on the "meaningfulness" of the concerns; that is, what the rowers aimed to do through their activity and in the specific setting they perceived. Therefore, concerns were considered "meaningless" when the rower could not put his/her concerns into words or when the researcher could not reasonably infer them from the surrounding detailed data.

Fourth, we identified the *typical perceptions* and *typical concerns* of the rowers. Typical components of the actors' experience were built through a thematic analysis (Braun & Clarke, 2006) that allowed us to characterize patterns of meaning, based on recurrence and congruence of singular meanings. The thematic analysis was conducted with "what participants perceive", and "how they actively regulate online their interpersonal states" in their mind when combining/delineating typical perceptions and concerns.

The last step consisted of *combining the phenomenological with the mechanical data*. This step consisted of determining the extent to which rowers reciprocally adjust their movements online in order to create/maintain a stable coordination under varying constraints and to which extent the rowers' adjustments reflect active or passive regulation. To this end, the degree of reciprocal compensation was scrutinized for each portion of the drive in order to account for how cadence impacted their amount of adjustments. Then, phenomenological data was used to interpret the extent to which such adjustments were governed by specific lived experiences of the rowers. These steps were performed with respect to each condition of cadence.

Statistical analysis

To analyze the mechanical data, statistical tests were applied. Analyses were carried out using the SPSS 17.0 statistical software package (SPSS, Inc., Chicago, IL, USA). First, differences between the four sessions regarding the mean CRP_{Drive} were analyzed using analysis of variance (one-way ANOVAs). Tukey's HSD post hoc were applied to the data sets (18, 24, 28 and 36.5 spm-sessions). Residuals were checked carefully for normal distribution using QQ plots and the level of significance was fixed at $p<0.05$. Second, cluster analysis was used to identify the similarities of reciprocal compensation patterns (i.e., Ratio R_V) between the different cadences for the three different portions of the drive. The four data sets of R_V were selected as input variables into a hierarchical cluster analysis method (Ward's linkage clustering using minimized Euclidean distances as the distancing metric). Cluster analysis was run for each portion of the drive section separately (i.e., entry, propulsion and release). This process allowed identifying the number of clusters that maximizes differences between clusters or groups and minimizes within-group differences on the dependent variables. For that purpose, the Fisher information (i.e. the ratio between inter-cluster distance and intra-cluster distance) was used to validate the number of clusters found in each portion of the drive section (i.e. the highest value of the Fisher information representing the optimal number of clusters). Cluster analysis was performed for a potential number of clusters from 2 to 3. The number of clusters was determined using the dendrogram, the agglomeration schedule coefficients, and the interpretability of the cluster solution (Aldenderfer & Blashfield, 1984).

Results

With respect to the four sessions in which subjects participated (i.e., increase of the cadence of stroke), the present section accounts for *i*) the degree of synchronization through the analysis of the magnitude of the CRP; *ii*) the reciprocal compensation performed by rowers through an analysis of our R_V parameter based on UCM; *iii*) the phenomenological account of rowers' experience through a thematic analysis; and *iv*) the matching of mechanical and phenomenological analyses.

The degree of synchronization

The magnitude of the CRP_{drive} was our measure of the degree of 1:1 synchronization. Analysis of variance showed a main effect of Session on the CRP_{Drive}, $F(3, 236) = 9.176$, $p = .00001$, $\eta p2 = .104$. Post-hoc analyses using Tukey's HSD indicated that CRP_{Drive} was higher for the 18spm-session ($\phi_{drive18} = -0.68 \pm 2.84$) than both the 28spm-session ($\phi_{drive28} = -2.86 \pm 3.12$; $p = .001$) and the 36.5spm-session ($\phi_{drive36.5} = -3.29 \pm 2.89$; $p = .0001$), though it did not differ significantly from the 24spm-session ($\phi_{drive24} = -1.54 \pm 3.34$; p = .427). The post-hoc analyses also indicated that $\text{CRP}_{\text{drive}}$ was significantly higher for the 24spm-session than the 36.5spm-session (p= .010), whereas the $\text{CRP}_{\text{drive}}$ of the 28spm-session was not different than the 24spm-session (p= .087) and the 36.5spm-session (p= .868) (Figure 2).

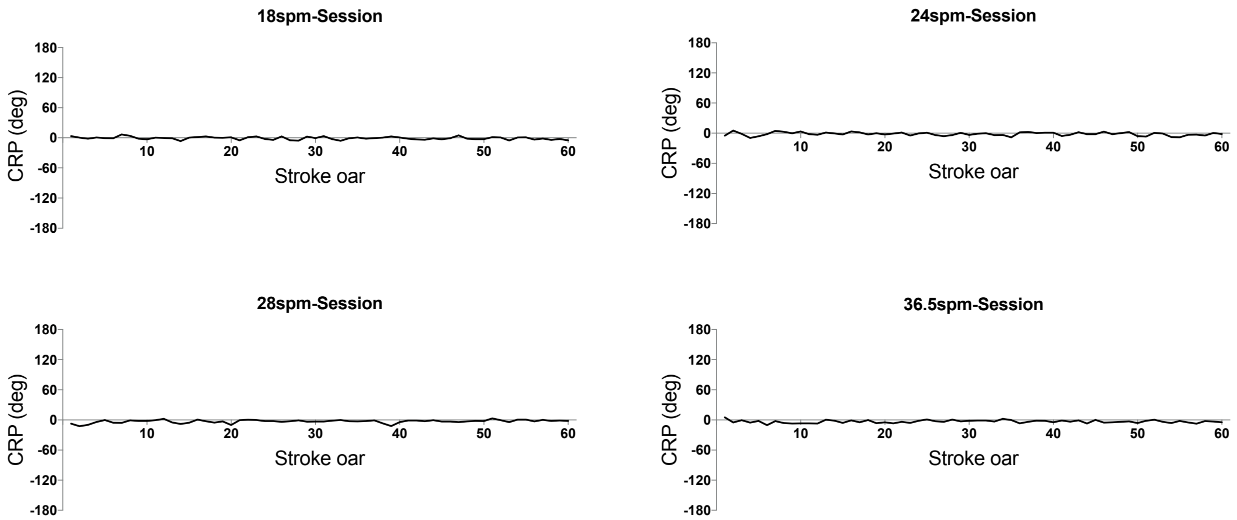

Figure 2: The $\text{CRP}_{\text{drive}}$ mean of the angle for each session

Reciprocal compensation (R_V)

As each point of the mean $\text{CRP}_{\text{drive}}$ was comprised between -20/20° (Figure 3) and boat velocity was not disrupted, conditions of interpersonal performance were met in order to perform the R_V analysis.

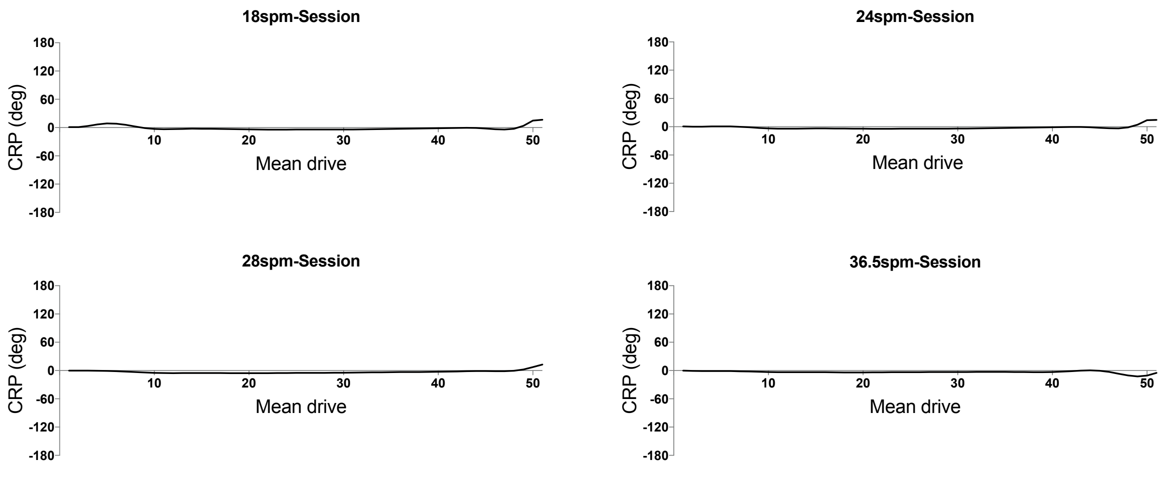

Figure 3: The mean $\text{CRP}_{\text{drive}}$ of the angle for each session

The Ratio R_V computed for every point of the drive portion with respect to each session was then submitted to a cluster analysis. Using the dendrogram a two-cluster solution was selected. The results of the cluster analysis on the mean drive Ratio R_V of the rowers' phase angle pointed out that none of the four drive Ratio R_V have the same pattern over the three portions.

For the entry, the Ratio R_V was similar across the three higher-cadence sessions (cluster 1= 24, 28 and 36.5 spm-sessions; cluster 2= 18spm-session), and a higher Ratio R_V was shown for cluster 2 (i.e., the 18spm-session). For the propulsive portion of the drive, both lower-cadence sessions exhibited a higher Ratio R_V than both higher-cadence sessions (cluster 1= 18 and 24 spm-sessions; cluster 2= 28 and 36.5 spm-sessions). For the release, the Ratio R_V was lower for the 28spm-session than for the three others sessions (cluster 1= 18, 24 and 36.5 spm-sessions; cluster 2= 28spm-session; see Figure 4).

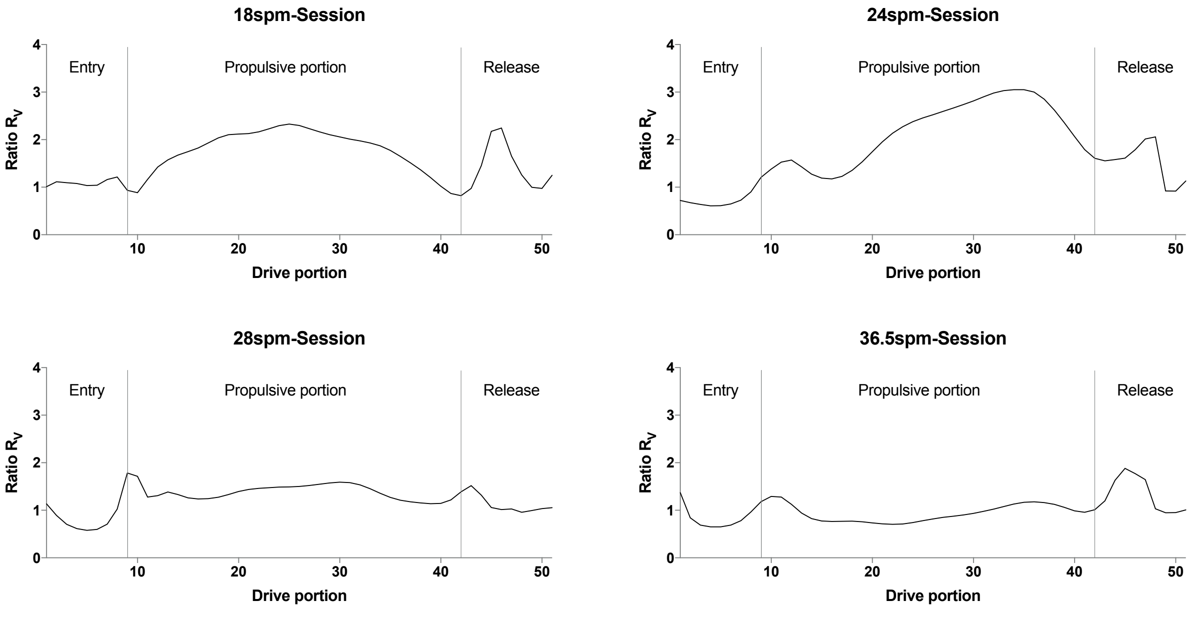

Figure 4: The Ratio R_V of the phase angle for each drive

Phenomenological account of rowers' experience

Targeting a phenomenological account of the experiences lived by the rowers, the thematic analysis identified 16 typical concerns and 21 typical perceptions during the entry and 20 typical concerns and 8 typical perceptions during the release (see Table 1 for further details)

Table 1: Illustration of the thematic analysis' results for each session

	Example of concerns:	Level of experience identified	Example of perceptions:	Level of experience identified
18spm-session				
Entry	*I try to feel what she does to be well together ahead [of the boat].*	Interpersonal	*To "add", ahead, because I put my legs but afterwards… I do not be necessarily very strong, because suddenly I feel too contracted.*	Individual
Release	*I know that for me, it's to push more on the back in order to well restart.*	Individual	*Yes, on the back yes, we feel that the boat slows down ... I feel it, I feel the boat goes slower.*	Boat
24spm-session				
Entry	*Yeah, I told him to "check" to reach the water together.*	Interpersonal	*Ahead, the oars' movements are faster.*	Interpersonal
Release	*I tried not to lie down too much on the back.*	Individual		
28spm-session				
Entry	*Here, it was to feed the hull. To increase the boat velocity.*	Boat	*Ahead, there are some gaps.*	Interpersonal
Release	*I tell her "to not get on my side", she is on my side and so I have the boat on me.*	Interpersonal	*It [the boat] is on me.*	Boat
36.5spm-session				
Entry	*In fact, to not be late, I shorten [the amplitude] ahead ...*	Interpersonal	*I felt that the boat was still hard.*	Boat
Release	*I thought that we were going to give a little speed to the boat by lengthening [the oar stroke].*	Boat	*I felt that we were shortening on the back.*	Interpersonal

The qualitative analysis shows that the phenomenological account of the rowers was very detailed at the entry and the release portions, as illustrated by the following excerpts: “Here we feel that we are less dynamic ahead” (Rower 1, Drive number 54 during the 18spm-session) and “I was trying not to go too far behind” (Rower 2, Drive number 26 during the 24spm-session). Moreover, while the rowers had as many concerns during the entry as in the release, they were more sensitive to what happened in their activity during the entry, as indicated by the prevalence of the perceptual components of their lived experience (Figure 5). Conversely, their consciousness of their lived experience was very poor during the propulsive portion of the drive: rather, rowers experienced the effectiveness of their oar stroke as an undefined whole.

The detailed documentation of the rowers’ experience during the entry and the release allowed for an identification of the level(s) of organization that supported their activity (i.e., individual, interpersonal and boat level; see Table 1). Regarding what rowers were concerned with, the entry was grounded in an interpersonal level for all sessions, in an individual level for the two lowest-cadence sessions (i.e., 18 and 24 spm-sessions), and in a boat level for the 18 and the 28 spm-sessions. Alternatively, the release was grounded in an interpersonal level for all sessions, in an individual level for the three lowest-cadence sessions, and in a boat level for all the 18, 28 and 36.5 spm-sessions.

Regarding what rowers were sensitive to (i.e., perceptual components), the entry was grounded in a boat level of organization for all the sessions, in an individual level for the 18, 24, and 36.5 spm-sessions, and in an interpersonal level for the three lowest-cadence sessions. Alternatively, the release was grounded in an individual level only for the 18spm-session, in an interpersonal level for the 18 and 36.5 spm-sessions, and in a boat level for the 18 and 28 spm-sessions.

Figure 5: Phenomenological account of the rowers about their concerns and perceptions during the entry and the release portion of each session

Combination of Mechanical and Phenomenological Data

Taken together, the mechanical and phenomenological analyses (Figures 4 and 5) converged on three points. First, entry and release are moments of increased reciprocal compensation (i.e., behavioral mutual adjustment), accompanied by very detailed lived experiences of the rowers. Second, the two lowest-cadence sessions involved more active regulation by rowers, as observed by more detailed phenomenological accounts of managing oars strokes, and the more pronounced mechanical behavioral mutual adjustment. Third, each session revealed some specificities in the activity of the rowers. The rowers in the 18spm-session exhibited a high capability of reciprocally compensating their movement, which was further supported by the increased amount of phenomenological accounts during the entry and the release, compared to the three other sessions. The rowers were not really sensitive to their release's activity in the 24spm-session while they reciprocally compensated their movement as much as in sessions of lower cadence. In the 28spm-session, though rowers were concerned with the individual, interpersonal and boat states during the release portion, they only had awareness of the boat states. Also, rowers had less behavioral mutual adjustment of their movement than in other sessions. The 36.5spm-session was also specific in comparison with submaximal sessions. Indeed, rowers achieved synchronization by being very active in managing their interpersonal states during the entry, as in other sessions, but by grounding this management in individual and boat dynamics, unlike in other sessions. However, the mechanical behavioral mutual adjustment was similar with the 24 and 28 spm-sessions.

Discussion

The purpose of the present study was to characterize how actors compensated their movement in a real-life joint-action task when facing different constraints of cadence. The second objective was to understand how the related lived experience of their joint action helps to understand their behavioral mutual adjustments. Thus, we hypothesized that (1) the amounts of behavioral mutual adjustments, as captured by behavioral measures, were related to different lived experiences during an ecological collective activity and (2) the actors were capable of adapting their active co-regulation to different constraints, as captured from both behavioral and phenomenological descriptions. To this end we examined how a pair of rowers changed how they row together during four sessions of incrementing cadence (i.e., 18, 24, 28 and 36.5 stroke per minute). First, the degree of interpersonal synchronization was investigated to provide insights into the crew functioning at a macroscopic level of analysis. The underlying behavioral mutual adjustment performed by the rowers to maintain their synchronization was measured with an adapted version of the UCM analysis. Correspondingly, the real-time subjective concerns and perceptions of both rowers were informed through a phenomenological analysis.

Effect of incrementing cadence on interpersonal synchrony within the crew

In light of the degree of synchronization, as measured by the continuous relative phase of the rowing angles, the results revealed that the degree of synchrony changed during the drive (i.e., the portion where the oar are under water) as the cadence increased. In the 18spm-session, rowers exhibited a higher level of synchrony than in both highest-cadence sessions (i.e., 28 and 36.5spm-sessions). In the 24spm-session, rowers exhibited a lower level of synchrony than in the 36.5spm-session. In other words, there was an increased loss of absolute coordination between the rowers' behavior as the cadence increased. Generally, the changes observed in synchrony signed the coming to the fore of a small delay between oar movements of the stroke and bow rowers with respect to the increase of the cadence. Such changes can be interpreted as the crew's solution to (partially) avoid channeling the asymmetrically-rigged boat into yawing during the drive. This result follows one of the predictions of the HKB model (Haken, Kelso & Bunz, 1985) mirroring the loss of stability in individual and interpersonal coordination when movement frequency increases in the oscillating limb paradigm (Schmidt, Carello, & Turvey, 1990).

However, achieving a delay in synchrony might also sign the emergence of a leader-follower-like (L-F) role division, becoming gradually visible, depending on the cadence. Of note is that the coach asked for a specific leader-follower relationship (i.e., the stroke leads and the bow rower follows; as defined in the rowing literature, e.g., Nolte, 2011), but in the case under study the direction of the relation has not been set up for the four studied cadences. In more detail, the L-F relationship was as expected by the coach during the 18spm-session, while it was inverted when the crew rowed at highest-cadences (i.e., the bow rower led the coordination). In rowing, Seifert and colleagues (Seifert et al., 2016, 2017) suggested that a L-F relationship could emerge under the influence of external constraints such as the wind, waves, changes in the river pathway, fatigue, race strategy, and/or teammate activity. In this light, the present study illustrates how the cadence could also probably be considered as a constraint leading to such L-F phenomena. Since cadence influenced the duration of each oar stroke, it probably led the rowers to adopt new or specific behavioral strategies to achieve efficient coordination. Acting as a constraint, imposed cadence led rowers to change the rate at which they oscillate their limbs, leading them out of their preferential rhythm and making the phase coordination to become less locked (e.g., the "detuning" hypothesis; Amazeen, Amazeen, Trefner & Turvey, 1997).

Rowers' activity of managing their joint action

The discussion of the rowers' activity of managing their joint action is ordered in three parts to discuss on one hand the mechanical results, and on the other hand the phenomenological results, and finally the combined results of theses analyses.

The rowers' behavioral mutual adjustment

Regarding the investigation of behavioral mutual adjustment, mechanical results pointed out that the cadence influenced differently the manner in which the rowers maintain their coordination. The results pointed out that the rowers seemed to co-regulate their movements more (a) during the entry at the 18spm-session, (b) during the propulsive portion at the 18 and 24 spm-sessions, and (c) during the release at the 28spm-session than the other sessions. Theses findings suggest that at the lowest-cadence the performance required a large amount of reciprocal adjustments of the rowers while the rowers co-regulated their movement to a lower extent during the higher-cadence sessions.

In this light, Hill (2002) discussed in double sculls how it is hard to maintain a mutual synchronization over a whole oar stroke during low cadences. In the same vein, Cuijpers and colleagues (2016) specified, "*crew coordination increased for the lower stroke rates (i.e., from 18 to 26 spm) but leveled at higher stroke rates (i.e., higher than 26 spm)*" (Cuijpers et al., 2016; p.6). The present findings showed that crew coordination was hardest to maintain at lower cadences and also required more behavioral mutual adjustments during the drive. When the boat velocity was slow, it can be assumed that it was harder to keep the balance of the boat, which required more behavioral mutual adjustments by the rowers. Alternatively, one can assume that higher-cadence sessions didn't required the rowers to achieve large behavioral mutual adjustments, because of co-agents being partially coupled through mechanical entrainment (i.e., as it can be the case in a tandem-like coupling).

Moreover, as Figure 4 shows, a peak of behavioral mutual adjustment occurred over the release portion suggesting that this part of the drive was very particular for the rowers' coordination whatever the cadence. This finding can be interpreted as the crew's solution to finish the drive together and to avoid rolling movements of the boat. In others words, the release portion, where the "finish" occurred, seems to be a specific moment where rowers adjust their activity in order to compensate all imbalances due to the propulsion, external constraints and/or boat movements. In other words, as suggested by Cuijpers and colleagues (2016), high behavioral mutual adjustments observed when finishing the drive suggest the release portion might be the particular moment at which rowers overtake the entire oar stroke defect.

However, the present findings also question the study of Cuijpers and colleagues (2016) by showing that the crew synchronization was related to less roll of the boat, but increased fluctuations regarding surge, heave, and pitch. Indeed, the adapted version of the UCM used here showed that crew coordination required different amounts of behavioral mutual adjustments. Moreover, for similar values of relative phase, different forms of behavioral mutual adjustment were observed. The need for rowers to have perfect crew coordination in order to avoid boat movements, as Cuijpers and colleagues (2016) suggested, should be coupled, in future research, with the degree to which reciprocal adjustments were simultaneously performed. In other words, future research could investigate the relation between the amount of behavioral mutual adjustments and the boat efficiency rather than merely focusing on crew synchronization.

In our mind, observing that similar values of the collective variable (i.e., close and stable crew synchronization as measured by CRP) were obtained through distinct forms of behavioral mutual adjustments in the three portions of the drive, and with respect to each session, can illustrate the "degeneracy" of the rower/rower system under study (Araujo & Davids, 2016; Seifert, Komar, Araujo & Davids, 2016). Degeneracy has been conceived as the presence of individuals' behavioral adaptations that maintain the function and/or the viability of the system, as captured at the level of collective behavior (i.e., the collective variable). Degeneracy processes can be inferred through the observation of changes in the system component behaviors (i.e., individual actors in a social system) while no changes are reported in the macroscopic function that the system maintains. Here, rowers maintained an absolute coordination (i.e., very locked phase synchronization) by changing their own phase angle during each moment of the oar strokes, as captured by the amount of behavioral mutual adjustment. These results argue for crew rowing behavior being a good candidate to study how degeneracy operates in social system facing interacting performance constraints (e.g., cadence, preferential rhythm, balance of the boat). Thus, as hypothesized in the present study, both rowers were able to actively co-regulate their interacting behaviors, so that the stability of their collective behaviors was maintained across all drive portions, and across various cadences.

Rowers' perceptions and concerns related to their joint action

The phenomenological account of the rowers' activity showed that the entry and the release portions of the drive were extremely detailed in terms of concerns and perceptions reported by the participants, in comparison to the propulsive portion. Unlike the mechanical data that showed different patterns between the different portions of the drive and between the cadences, here, the phenomenological data clearly showed that rowers were more, even only, focused on their coordination during the entry and the release portion, and this occurred for each cadence. In other words, the entry was a crucial portion were the rowers needed to be very aware of their activity, as observed by the higher amount of perceptions reported by the rowers during this portion of the drive in comparison to the release portion (for which typical perceptions were used half as much than for the entry). However, the entry was less associated with concerns to co-regulate to propel the boat, as reported by the rowers. This result highlights that both specific portions of the drive were very salient at the pre-reflective level of consciousness for the rowers during rowing performance. It can be suggested that rowers (co-) regulated their coordination on the basis of two salient moments of their whole drive phase that were just after the catch and just before the finish. Therefore, and as experienced by the rowers, the remaining portion of the drive movement (excluding entry and release) unfolded as when a swing is pushed. The propulsive portion was sufficiently entrained to let it unfold out of extensive co-regulation. In the least, considering the release portion as the preparation to the finsish starting the recovery portion, the large amount of meaningful activity as observed at the catch is a key-moment for participatory sense-making while the majority of the rest of the drive portion was achieved through less meaningful co-regulation, probably facilitated by an important mechanical coupling.

Combining phenomenological and behavioral analyses

Taken together, the phenomenological and behavioral analyses question the relationship between the degree of synchronization achieved during the drive phase and the related degree of participatory sense-making. From a theoretical point of view, coupled systems may undergo changes in the level of coordination achieved over time, going from absolute to relative coordination (Von Holst, 1973). In this light, Kelso (1995) argued that absolute versus relative coordination illustrate two possible forms of dynamical synchrony. Absolute coordination is associated with a pure phase locking, in which the synchrony is nearly faultless: the two series of events are thoroughly entrained. Relative coordination, in contrast, is achieved through more possibilities, since the coupled oscillators maintain a coordinated pattern while being not perfectly entrained. Relative coordination generally occurs when oscillators are moving at (slightly) different frequencies (e.g., Gorman, Amazeen, Crites & Gipson, 2017).

In this study, the stability of the crew coordination index suggested that the present coxless-pair crew operated, during the drive portion, with absolute coordination to propel the boat. This absolute coordination was shown to be accompanied by non-negligible behavioral mutual adjustments that allowed the given coordination to be maintained. Furthermore, high levels of participatory sense-making were found in companion to such behavioral mutual adjustments. Interestingly, De Jaegher and Di Paolo (2007) suggested that absolute coordination should be accompanied by high participatory sense-making, without any empirical evidence for such an assumption in the literature. Our results suggest that the observed peaks near point 10 (i.e., catch) in figure 4 and the peaks near point 44 (i.e., the finish) on the behavioral mutual adjustments were the same as the increased participatory sense-making phases. Thus, the present study provides empirical evidence of De Jaegher and Di Paolo’s suggestion (De Jaegher & Di Paolo, 2007; Di Paolo, Rohde & De Jaegher, 2010), and goes deeper by observing that increases in participatory sense-making are related to increases in behavioral mutual adjustment, probably caused by a mutual awareness requirement. Moreover, when one considers that the release portion of the rowing cycle reflects a transition from an absolute coordination dynamics to a relative one (i.e., when oars are out of water), the hypothesis according to which transitions from distinct coordination states reflect salient moments of social encounter should be associated with enhanced participatory sense-making (Di Paolo, Rohde & De Jaegher, 2010) seems to be in accordance with our results.

In sum, and as revealed by the incrementing cadence conditions, the nature of the coordination (i.e., absolute or relative) would be probably less responsible for increases in participatory sense-making than the amount of behavioral mutual adjustment achieved by co-actors, especially when one consider that absolute coordination could be achieved through mechanical entrainment of both interactors (i.e., in a tandem-like functioning).

Limits and Conclusion

There are limitations to this study. In terms of internal validity, the cyclical repetitive movements of rowing may question the capability of the rowers to adequately comment on their activity and exactly remember each stroke during the retrospective interview. While this question remains open, rowers' accounts of their lived experiences were carefully checked using the video recording, the available mechanical data, and through a comprehensive verification of the consistency/relevance of what was commented by the participants. Aspects of this study also limit the generalizability of the findings because the study involved relatively small data sets, and only one crew was investigated, suggesting that the present results can be mainly transposed to other cases exhibiting similar characteristics (e.g., crew experience, stroke-rate).

In this article, we described the relation between behavioral mutual adjustments and meaningful co-regulation within a coxless-pair crew and how the behavioral mutual adjustment at each part of the drive portion changes under different cadences. Finally, we explored the potential of an adapted version of the UCM to contribute to the current understanding of team functioning. Among the key results was that the rowers changed their L-F relationship under different cadences as an adaptation to maintain boat efficiency. Moreover, the individuals' behavioral adaptations captured by the adapted version of the UCM (i.e., the behavioral mutual adjustments) allowed them to maintain the stability of the collective variable (i.e., CRP), signing the presence of degeneracy in the rowers' social system. Finally, increases in rowers' participatory sense-making accompanied the increase in behavioral mutual adjustment, providing empirical support of the Di Paolo, Rohde and De Jaegher hypotheses (Di Paolo, Rohde & De Jaegher, 2010).

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UNIVERSITE
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Thèse de Doctorat

Mehdi R'KIOUAK

« Ramer ensemble » en aviron : entre régulation inter- et extra-personnelle
Contribution à une approche enactive des couplages sociaux

"Rowing together": between inter- and extra-personal regulation in rowing
Contribution to an enactive approach of social couplings

Résumé

En s'inscrivant dans une approche énactive et interdisciplinaire de la coordination interpersonnelle (Bourbousson, 2015), cette thèse visait à mieux comprendre la manière dont des rameurs expérimentés en aviron (co-)régulaient leur activité collective en temps réel en relation avec leur bateau. Trois études de cas sur des équipages en deux de pointe sans barreur composent cette thèse.

L'Étude 1 pointe que (a) les deux rameurs faisaient rarement simultanément l'expérience de leur action conjointe, (b) certains coups de rame étaient cependant simultanément vécus comme efficaces ou non-efficaces, et (c) les rameurs régulaient activement leur activité collective en s'ajustant mutuellement aux comportements de leur partenaire (i.e., (co-)régulation interpersonnelle).

L'Étude 2 montre qu'à l'issue du programme d'entraînement (a) la proportion du nombre d'expériences simultanément vécues par les rameurs relatives à leur action conjointe avait significativement augmentée, et (b) les rameurs régulaient activement leur activité collective en s'ajustant aux variations dynamiques de leur environnement matériel commun, le bateau (i.e., (co-)régulation extra-personnelle).

L'Étude 3 pointe que les rameurs modifiaient la nature de leurs ajustements mutuels en relation avec différentes contraintes de cadence imposées. En outre, les adaptations comportementales des rameurs ont suggéré l'existence d'une propriété de « dégénérescence » (Araujo & Davids, 2016) dans le système social que constituent les rameurs. Enfin, les expériences vécues rapportées par les rameurs étaient concomitantes des moments saillants d'ajustements mutuels suggérant des formes de « participatory sense-making » dans les instants de co-régulation (Di Paolo & De Jaegher, 2010).

Mots clés :
Coordination extra-personnelle, (Co-)régulation active, Méthodologie interdisciplinaire, Stigmergie, Coordination interpersonnelle, Ajustements mutuels, Approche énactive

Abstract

By adopting an enactive and interdisciplinary approach to interpersonal coordination (Bourbousson, 2015, De Jaegher & Di Paolo, 2007), this thesis aimed to better understand the way in which experienced rowers in rowing (co-)regulated their collective activity in time in relation to the boat. Three case studies of coxless-pair crews composed this thesis.

Study 1 points out that (a) the two rowers rarely experienced simultaneous joint action at the same time, (b) there were simultaneously experienced oar strokes as effective or detrimental, and (c) suggested that rowers actively regulated their collective activity by adjusting to each other's behaviors (i.e., interpersonal (co-)regulation).

Study 2 shows that at the end of the training program (a), the proportion of the number of experiences simultaneously lived by the rowers relative to their mutual coordination significantly increased, and (b) suggested that rowers actively regulated their collective activity by adjusting to boat behavior (i.e., extra-personal (co-)regulation).

Study 3 points out that the rowers modified the nature of their mutual adjustments in relation to different imposed cadence constraints. In addition, behavioral adaptations of rowers suggested the existence of a "degeneration" property (Araujo & Davids, 2016) in the social system constituted by the rowers. Finally, the lived experiences reported by the rowers were concomitant with the salient moments of mutual adjustment, as observed in the behavioral data, suggesting participatory sense-making forms in the moments of co-regulation (Di Paolo & De Jaegher, 2010).

Key Words:
Extra-personal coordination, Active (co-)regulation, Interdisciplinary methodology, Stigmergy, Interpersonal coordination, Mutual adjustments, Enactive approach

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