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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

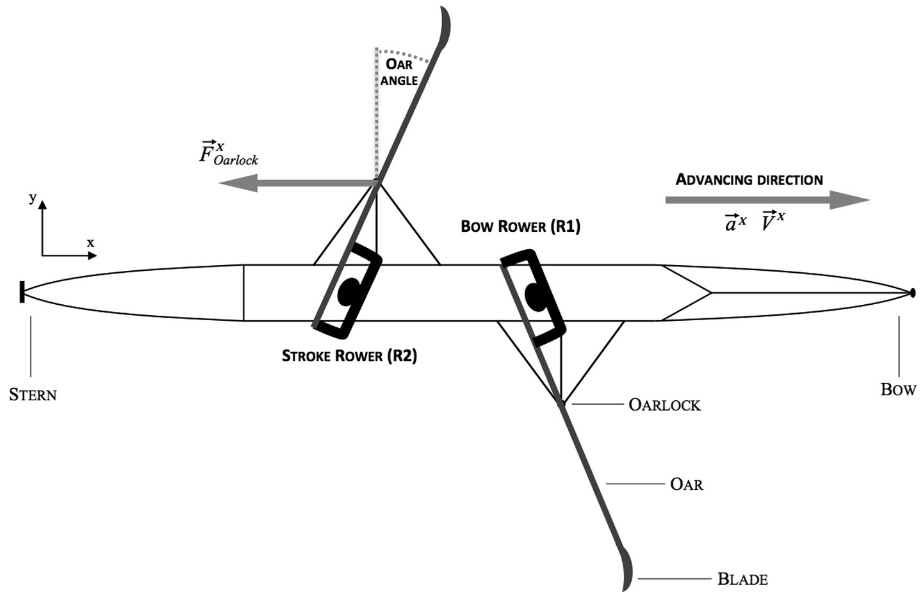


Fig. 1. Bird's-eye view of a coxless pair. The onboard measurement system (Powerline, Peach Innovation) records the components of the forces applied by the rowers to the oarlock along the x-axis (in the direction of the boat's movement), the acceleration, the speed of the boat, and the angle formed by 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 ($^{\circ}{\cdot}s^{-1}$), and (h) the mean of the strokes' variability regarding angular velocity, computed from the standard deviation's values obtained on each cycle ($^{\circ}{\cdot}s^{-1}$).

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 (%).

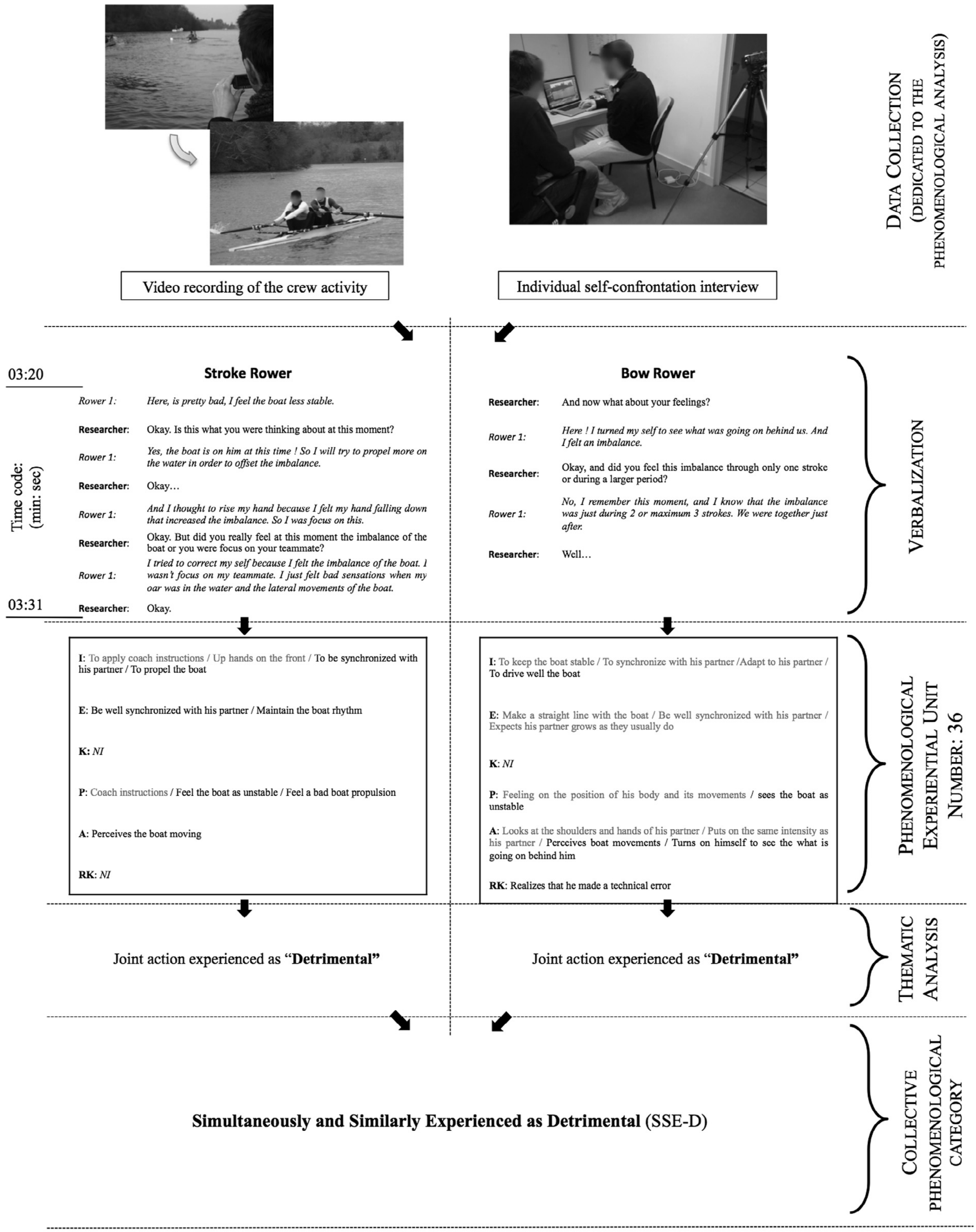
At the boat level of analysis the following indicators were retained for each cycle (a) the mean of the boat's velocity ($m{\cdot}s^{-1}$) and (b) the mean of the boat's acceleration ($m{\cdot}s^{-2}$).

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



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.

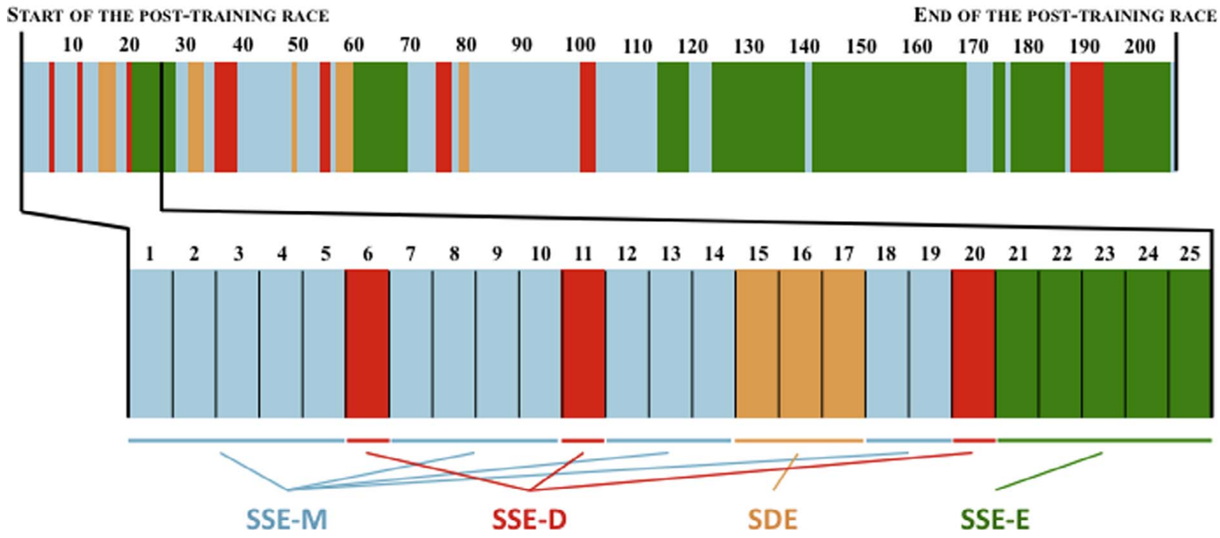


Fig. 3. Repartition of the lived experiences throughout the race, as obtained from a collective level of analysis. *Note*: SSE-M, Joint action Simultaneously and Similarly Experienced as Meaningless; SSE-D, Joint action Simultaneously and Similarly Experienced as Detrimental; SSE-E, Joint action Simultaneously 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 $_{SDE}$ angle CRP = −7.70° ± 12.17° *versus* Mean $_{SSE\text{-}E}$ angle CRP = −11.16° ± 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 $_{SDE}$ angle CRP = 1.38° ± 22.45° *versus* Mean $_{SSE\text{-}D}$ angle CRP = −15.03° ± 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 $_{SSE\text{-}D}$ boat velocity = 2.28 m·s^{-1} ± 0.06 m·s^{-1} *versus* Mean $_{SSE\text{-}E}$ boat velocity = 2.21 m·s^{-1} ± 0.06 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

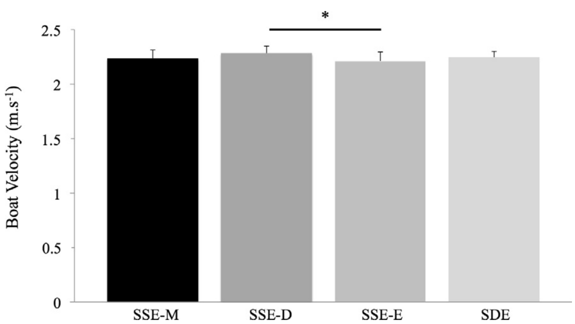


Fig. 4. Mean values and standard deviations of the boat velocity in each collective phenomenological category during the first part of the drive phase. *Note*: SSE-M, Joint action Simultaneously and Similarly Experienced as Meaningless; SSE-D, Joint action Simultaneously and Similarly Experienced as 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

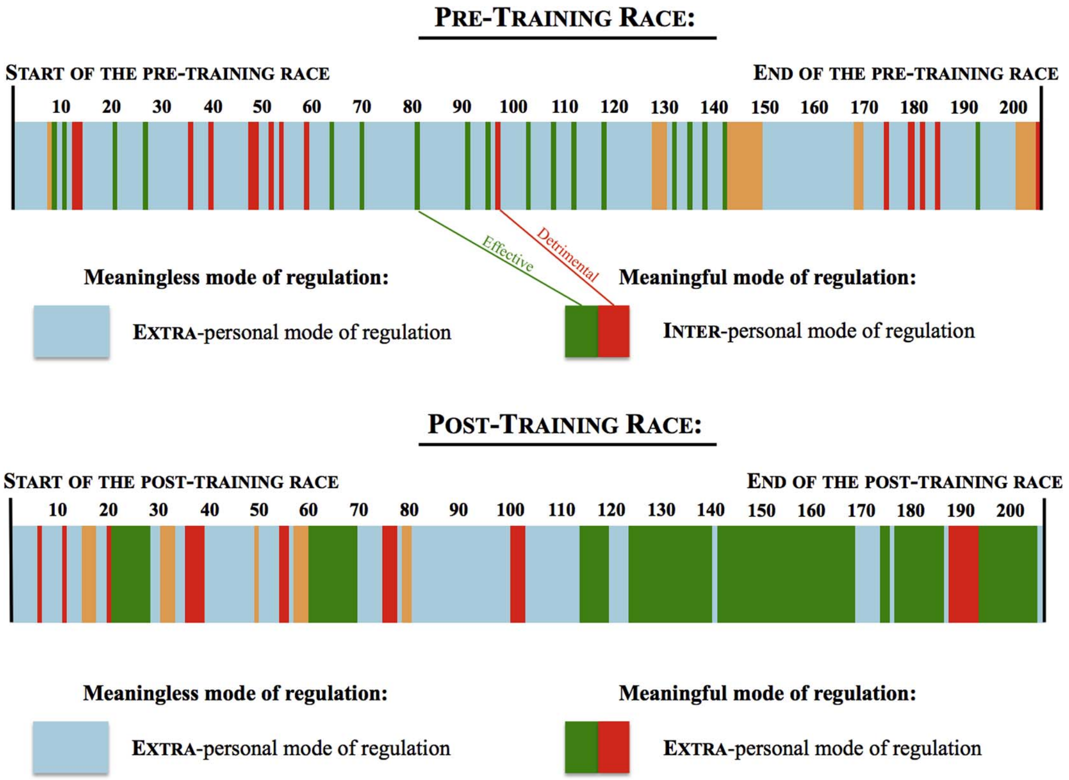


Fig. 5. Evolution of the collective phenomenological categories and the related modes of co-regulation across the period training.

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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