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ABSTRACT

We often think of time in dualistic terms: as a property that is inherent to the objective world on the one hand, and as the subjective apprehension of its passage on the other hand. Yet, rather than being a mere cognitive estimation of outer durations, the felt and observable temporality of our behavior has a complex form that implicates many timescales, reflecting the interactions between multiple inter and intra subjective processes. We thus propose that the shape of time as we experience it emerges from the dynamics of our interactions with others and should be described as the entanglement of our respective intrinsic temporalities (Laroche et al., 2014). Indeed, time, instead of being a mere property of the world or an intra-cerebral phenomena, is something that we « make together ». Our very sense of being in time is intertwined with those of others, making time a socially constituted dimension of experience and activity.

Collective Improvisation (e.g. in dance, music...) has been described as the very practice of of temporality negotiation (Butterfield, 2010, Chauvigné et al., 2018, Walton et al., 2018, Noy et al., 2011, Vicary et al., 2017), in other words, a practice of making time together. In our research project (Himberg et al., 2018), where joint dance improvisation is used as a paradigm or a tool for the transdisciplinary study of the dynamics of social interaction, shared temporality, understood as an emergent property of the above mentioned dynamics, naturally takes a central stage. To explore how time is made through our interpersonal interactions, we developed a number of protocols based on improvisational scores and practices that gauge how and to what extent our sense of timing is affected or constituted by our interactions with others. These protocols share a number of features. Most importantly the temporal contour of the activity is not pre-defined or externally prescribed but rather emerges from the interactions of the participants. The scores (or the rules of the game) are kept simple and open-ended enough so the activity

remains creative and enjoyable, while the movement patterns can be tracked and analyzed. Finally, we attempt to couple the observed kinematics with subjective experiential reports. Together, our protocols of collective dance improvisation explore the collective formation (and disruption) of temporal shapes at multiple timescales through body movements and its accompanying socio-affective experiences.

THE DYNAMICAL, MULTISCALE AND PARTICIPATORY NATURE OF TIME MAKING

From dualistic to autonomous-relational multiscale time

Time is, at least tacitly, often taken for granted as a pre-existing category or an objective dimension of our world. By flowing uninterruptedly, it seems to be permanently there, preceding both the phenomena that occur in its course and our experience. We thus tend to assimilate time to its measurement, as classical physics does: a linear and regular unfolding of successive units that can be universally captured in terms of duration (Varela, 1999). By taking objective properties of the world as a reliable starting point and then wondering how minds form inner representations of this outer reality, cognitive scientists might be tempted to assume that we experience time by reconstituting temporal lengths (as if they were a separable trait of external events), having recourse to some internal clocks or counters for instance (Treisman et al., 1990 ; Wing & Kristofferson, 1973).

Such duality between the outer time of the world-as-objects and the inner time of the subject was noticed by Husserl (1928): we perceive outer events as having a duration, and our inner felt experience of those events is itself enduring. Yet, he pointed out that we do not experience these aspects separately: they present themselves in a unified fashion. It is so because temporality is the most irreducible, fundamental level of lived experience: no experience happens outside time, and they all present a similar temporal structure, where the present moment is lived in the interplay between retention and protention. Retention designates the context formed by past experiences in the light of which the present is experienced (the note felt in the context of a melody). Protention designates the soft anticipation of upcoming experiences that gives the present experience an horizon toward which it tends (the implicit sensation that the melody is going somewhere). As retention holds previous experiences, it holds previous retentions as well, forming a nesting of contexts formed by past experiences (the current note heard in the light of not only its interval with the previous one, but also of the whole melody and higher-level structures - for example when that note is the only variation of a melody that was repeated earlier). This gives the present experience a thick, complex and kind of fractal structure (Laroche et al., 2014 ; Gallagher et Zahavi, 2014). Past protentions are retained as well and how they get trumped or confirmed by the unfolding of external events allows us to experience their temporal organization within the lived flow of experience itself (rather than dualistically, as a representation that seeks to duplicate reality).

Enactive and dynamical approaches can jointly account for the endogeny of temporal experiences and their relational nature with outer temporalities (Laroche et al., 2014). In effect, our behaviors and experiences emerge from a background where many parts of our body interact with each other at multiple intricate timescales. Behaviors' and experiences' temporal form thus carry the mark of those dynamics: the nesting of ongoing dynamical trajectories into slower dynamics provides a retentional context while dynamical tendencies of parts to couple and decouple form protentions (Varela, 1999). Intrinsic temporality can then be informed by external events (Doelling et al., 2019), which perturbs and modulates our own dynamical background over time: we « sense » temporal events, yet in our own terms. This explains how we can feel the underlying pulse of music even when no acoustic events coincide with those pulses (Large & Snyder, 2009), and why our behaviors can unintentionally entrain to the structure of external events (Varlet et al., 2017). However, experiencing is not a passive process. Rather, it emerges from our sensorimotor coupling: what I do affects what I sense (Varela et al., 1991). Body movements thus frame the temporality with which we attend to, process and experience sensory events (Morillon et al., 2014 ; Hammerschmidt & Wöllner, 2020 ; Tichko et al., 2021). As a result our behavior can embed both the complex structuration (Stephen & Dixon, 2001) and the multiscale nature (Toiviainen et al., 2010) of sensory events with which we coordinate. In sum, sense-making (making the world a meaningful place of experience by actively making of our senses through our movements) is temporal in nature, and this temporality is both endogenous (it stems from the dynamics of our constitutive body) and relational (it is modulated by the temporality of external events and takes form within a process of sensorimotor interactions ; Laroche et al., 2014).

The intersubjective embodiment of time

The relations we have with others are constitutive of what we come to call our world. When two or more agents interact, their respective sensorimotor coupling become themselves coupled (McGann & De Jaegher, 2009): what I do factors in what you sense and therefore in what you do next, which factors in my own sensorimotor coupling in return (Hari et al., 2009). We thus become part of each other's coupling and, subsequently, of each other's resulting experiences (Fuchs & De Jaegher, 2009). Because these experiences are temporal in nature, we thus participate in each other's temporality. We spontaneously align the rhythm of our words (Himberg et al., 2015), our movement properties (Issartel et al., 2007) and we keep a trace of other's movements dynamics after our encounters (Nordham et al., 2018), even when only spectating the other (Bachrach et al., 2015).

Moreover, the very dynamics of our interactions can self-organize, giving rise to collective dynamics (De Jaegher & Di Paolo, 2007). Interactions have a temporality of their own, coherently evolving at their proper timescale (Gratier, 2007). In effect, collective dynamics can often constrain individual activities and coordinate them, for example by entailing emergent pulses that are shared across interacting agents (Oullier et al., 2008). Therefore, individual temporality is constituted by the collective dynamics that emerge from our encounters with others. Given the complex, multiscale nature of our respective temporalities, the coordinated outcomes of interaction go beyond mere synchronized entrainment. Instead, we come to share

our retentional background and protentional horizon, and the entire complexity of the dynamics that underlie our sensorimotor coupling thus get aligned within the interaction process (Laroche et al., 2014).

Coherent coordination at multiple and distinctly functional timescales has been observed from infancy onward in mother-child interactions, and the quality of coordination across scales is deeply associated with affective and cognitive outcomes (Gratier & Apter-Danon, 2009). Interaction dynamics thus constitute an intersubjectively lived temporality whose coordination is at the source of common meaning making (Gratier & Magnier, 2012). This has been observed in adult conversation as well (Fusaroli et al. 2014 ; De Jaegher & Di Paolo, 2007), it impacts affective outcomes of psychotherapeutic interventions (Ramseyer & Tschacher, 2011) and many lab experiments have shown the pro-social and affiliative effects of temporal coordination of movements (Marsch et al., 2009). In short, the experience of making time together matters cognitively and socio-affectively. Unfortunately, most current experimental set-ups related to temporal coordination use sensorimotor lab tasks that do not reflect the complex temporal organizations of ecological social interactions and that aren't affectively involving for or meaningful to participants (e.g. dyadic synchronization tasks). How, then, to better study the key mechanisms of interaction that subtend what we coin as "participatory time-making" (in reference to the participatory sense-making it allows - De Jaegher & Di Paolo, 2007) ?

PARTICIPATORY TIME-MAKING IN IMPROVISATION & GIGs

We hold that improvisational activities constitute a relevant tool to explore how we bodily make and experience time together. It is often taken for granted that, as our activities are generally poorly scripted, improvisation reflects the ecological condition of daily behaviors. However, improvising because of a lack of constraints or rules and improvising for the sake of it are different in nature (Krueger & Salice, forthcoming). In the later case (e.g. artistic collective improvisation in dance or music), the intersubjective negotiations of temporality becomes the focus of interactions and a source of meaningfulness (Butterfield, 2010, Chauvigné et al. 2018, Walton et al. 2018, Noy et al. 2011, Vicary et al. 2017). Improvisers thus have a rich first-person perspective on the active sharing and making of temporality. More than an object of inquiry, improvisers are thus researchers within that field. The temporal organization of interaction in collective improvisation, being under-specified (Goupil et al., 2021), has to be co-enacted and co-regulated by the performers. Furthermore, the way temporality takes form in the course of the performance becomes the impulse that incites further regulation of the group coordination. Sharing temporalities and regulating that sharing (especially when it collapses) thus becomes one of, if not the most central element that motivates and inspires the organization of the improvised interaction (Laroche & Kaddouch, 2014 ; Walton et al., 2018). Making time together in artistic collective improvisation is therefore both a means (coordinating the group's activity) and an end (the group aims at producing aesthetically interesting temporal shapes or structures). In short, collective improvisation consists in the very practice of "participatory time-making".

To understand participatory time-making in collective improvisation, we need to understand the articulation between emergent temporal coordination and the resulting experiences that motivate strategic decisions about its co-regulation (Saint-Germier & Cannone, 2020). In other words, third-person observations and first-person experiences of interaction dynamics should be explored hand in hand (Dumas et al., 2014). To do so, we progressively built methods and tools of practice and observation to explore participatory time-making. Our approach consists in gathering experts from different fields (science, humanities, and « movement experts » such as dancers and body-practitioners) in workshops (over days) and regular meetings and discussion where perspectives, observational knowledge and experiential feelings challenge each other. We thus bring scientists to the dancefloor as much as we bring dancers to the lab. Scientists can then reflect experientially on their own objects of study while they are being guided by movement experts, who gain a new perspective on their own practice. This helps us design interventions and scores for collective improvisation, and methodological and technological devices to observe and analyze them both quantitatively and qualitatively. We then test the scores and the tools with the public (dancers or not) in workshops of usually shorter duration (a dozen participants during half a day) to further refine their content.

In particular, we bring scientific and artistic worlds together by designing GIGs, or « Group Improvisation Games » (Himberg et al., 2018). GIGs are scores that keep instructions sufficiently open-ended to allow for spontaneous and creative interactions while keeping a format that is amenable to empirical studies, taking the form of little experiments, or trials across which we vary some details (« conditions »). More precisely, we follow a chart of design principles that emerged from our collective experiencing, experimenting and discussion about various protocols, and whose features aim at echoing the epistemological background presented above. Here are some of the main principles :

- 1) GIGs are designed iteratively as a function of the experiences they elicit when we practice them collectively.
- 2) To help focus attention on the processes of moving and interacting and enrich their associated experiences, GIGs are open-ended (no pre-specified goals or normative performances requirements)
- 3) GIGs accept a plurality of solutions to stimulate both divergent (exploring various alternatives) and convergent thinking (choosing among them).
- 4) GIGs incite interactive generativity: simple individual actions can generate more complex collective forms.
- 5) GIGs are mainly for groups beyond the dyad to emphasize de-centralized group properties.
- 6) GIGs allow tracking both first-person experiences and bodily activity.
- 7) GIGs allow novices to take part by keeping a balance between the richness of artistic practices and empirical formats.
- 8) GIGs elicit shifts in experiences and behavior to help bridge the affective reception of particular moments of interaction and the quantifiable dynamics that underlie them.
- 9) GIGs avoid verbal communication in order to focus on movement relationality.
- 10) GIGs are engaging, fostering interaction's richness and associated experiences.

This is an ecology of guidelines: GIGs emphasize some principles at the expense of others, depending on the empirical question.

Below, we present a few examples of GIGs and the technological and methodological devices that we are currently developing to explore their dynamics. We accompany these examples with illustrations of the analysis that can be performed on data collected during GIGs. We will specifically highlight the multiscale nature of the temporal processes at play. After a brief presentation of 3 other GIGs, we will more particularly focus on one of them : the 4-person mirror game.

EXPERIENCING AND EXPERIMENTING PARTICIPATORY TIME-MAKING

The Rhythm Battle :

The Rhythm battle GIG is inspired by a Congado tradition where marching bands « chant » the identity of their group and strive to maintain it when they stumble across each other (avoiding entraining to the other groups' rhythmic pattern ; Lucas et al., 2011). This situation allows to study in-group coordination as well as out-group entrainment and distraction's inhibition. In Himberg et al. (2018), we invited 3 groups of 12 to 14 participants to the lab, 10 of which wore accelerometers on their chest, and divided each of them into 2 subgroups (« bands »). Bands were placed on opposite sides of a large room separated by movable walls. They were requested to come up with a rhythmical pattern of their own using their body as a percussion instrument, each band at a different tempo given by a metronome. Once they had chosen and practiced their identifying pattern, the walls were removed and bands could perceive each other performing. Then, metronomes were shut down, which enhances the potential coupling between bands. Finally, bands were asked to maintain their respective patterns as they walked across each other. Results based on pairwise correlation of tempi between the different participants showed the spontaneous and unintentional tendency to entrain to the rhythm of out-group members (making the temporality of others a bit of our own). Most interestingly, the degree of entrainment to other participants (of in and out-group) was correlated with subjective feelings of closeness with them. This highlights how social affiliation and interpersonal movement coordination work interdependently.

The Grid Game :

The grid game is a GIG based on turn-taking logic which allows to explore the non-verbal collective creativity in free play (Kalaydjian et al., in prep). Groups of 4 to 6 participants are presented with a 4*4 grid drawn on the floor with tape along with a few more objects at their disposal (e.g. scissors, tape roll, boxes). Participants are given only instructions that they can perform one action at a time, and need to wait for somebody else to take a turn before they can perform another action. We observed both groups of children and adults inventing rules and forms together by elaborating on each other's action. Here, participatory time-making is not manifest in the form of synchrony but rather, as in a conversation, as the negotiations of turn taking, the handling of overlaps between turns and the rhythmic organization of sequences of turns. We are currently analyzing kinematic data extracted from video recordings to assess the

relationship between changes in temporal dynamics and moments of creative leaps during the game.

Articulations :

Articulations is a Virtual Reality (VR) based GIG where two immersed participants (wearing cordless headsets) move freely in a minimal virtual landscape. Their VR avatars consist of 3 spheres corresponding to their head and two hands, whose motion is captured by trackers placed on them. This minimal representation (we name Diminished Reality, Vuarness et al., under review) focuses the attention of the participants to the quality of their movements and how they relate to their partners'. Most participants start to naturally interact with the three spheres representing their partner (even though no instruction is provided to interact) in what we consider to be a form of dance improvisation. VR gives us control over sensorimotor mappings and the environment, allowing us to introduce small changes throughout the experience to tackle specific questions. For example, the representation of one's own hand can suddenly disappear making the participant fully invisible to herself (but not to the partner). The VR setup records all movement data associated with the spheres. This allows us to compare (relational) movement patterns in the different conditions (e.g. own body's avatar visible vs. invisible) and to correlate these patterns with subjective reports we collect post experience. In a recent experiment (Laroche et al, accepted) we found that partner's hands kinematics were more coordinated across time when participants could only see their partner's body but not their own. Furthermore, the slower participants moved their head in the horizontal plane (which reflects whole-body displacements) and the more similar to their partner they did so, the more they reported that this specific condition was enhancing their feeling of (affective) closeness to their partner. The absence of visual feedback from one's own movement invites or pushes participants to anchor their temporal organization to that of their partner. In turn (as we found with the rhythm battle but this time with a handle on the causality) the fact that increased temporal co-organization produces a stronger inter-personal bonding further demonstrates the centrality of making time together in sociality.

To better understand these observations in the context of the current proposal, we re-analyzed interpersonal kinematic patterns (and their relation with experiential reports) at multiple timescales. We computed cross-spectral coherence, which gauges the co-variation between 2 signals at separate frequency components, allowing us to more precisely identify the timescales at which coordination occurred. Coherence between partners' (overall) hands' velocity and lateral head displacements was computed using sliding windows of 1024 data points (about 10 seconds). Coherence was then averaged for each dyad and condition in 4 broad frequency bands (0.15-1Hz ; 1-4Hz ; 4-7Hz ; 7-10Hz). We compared coherence across conditions of body visual feedback by using Wilcoxon signed-rank tests.

Coherence was significantly higher in absence (compared to presence) of visual feedback of one's avatar in the 1-4Hz (and marginally in the 4-7 Hz) frequency band for hands velocity, and in the 0.15-1Hz (and marginally in the 1-4Hz band) frequency band for horizontal head velocity (see Table 1 for statistical details). Furthermore, coherence of lateral head motion in the

0.15-1Hz band in absence of feedback of one's own avatar correlated with the reported experience of feeling closer to the partner in that condition ($r = .55$, $p = .013$). This novel analysis revealed that hand movement and head/full body displacement get coordinated at different timescales. Second, it is at the slower timescale of lateral head motion that relational kinematic patterns and socio-affective experience were linked: slower whole-body displacements and postural changes are therefore more likely to be involved in the link between relational movement and affective connection than faster gestures.

The Mirror Game :

The MG is an improvisation practice from theatre which has been popularized in scientific research by Noy et al. (2011), where dyads synchronize freely improvised movements along one dimension without verbal communication. When a leader was designated, followers produced more jittery motions that reflect small corrective submovements. When leadership was shared (and therefore negotiated kinematically), movements had a smoother shape that is proper to mutual interactions (Noy et al., 2011) and correlated with both physiological coordination and first-person feelings of togetherness (REF). When interactions were mutual, individual kinematic properties blended together and form an emergent intersubjective behavioral space (Słowiński et al., 2016). The MG thus helps to study interpersonal attunement and the emergence of intersubjective temporality in the interaction process.

To go beyond the patterns of interaction inherent to the dyadic situation (one follows the other or they interactively guide each other), we expanded the MG to a 4-person setting. This installs conflicts between possible choices : how to negotiate common movements and who to follow ? Resulting divergences thus need to be coordinately and strategically dealt with. This constitutes an ecological case of joint improvisation that reflects the main « coordination problems » identified in music improvisation: the consolidation of an idea, and the articulation between different ideas (Goupil et al., 2021). The advantage of the MG, however, is that it doesn't necessitate any specific expertise. In fact, it even facilitates the study of the very effects of expertise.

In a small-scale study (Himberg et al., 2018), participants familiarized with the MG in a dyadic setting, then performed it in groups of 4 participants, standing in circle and pointing a finger at its center. Next, they experienced a group improvisation intervention before playing the 4-person MG a second time. To explore their participatory time-making, we combined kinematic analysis (coordination of whole-body quantity of motion and cross-correlation between fingers acceleration), post-experiment first-person interviews, personality questionnaires and third-party qualitative annotations.

First, we analyzed a group of 4 dancers. In the first MG, group coordination was poorly coherent: participants moved at different speeds, with dissimilar movements and large lags between individual shifts. Then, the group performed an improvisation game (holding a large sheet of paper together then dropping it and continuing to move as if still holding it). In the second MG that followed, they developed more similar shapes, their finger movement got more

correlated at narrower lags, entailing smoother coordination as in Noy et al. (2011). It is possible that the specific form of the intervening improvisation practiced inspired (or primed) a strategy (maintaining the interpersonal space constant) to solve the complexity of the coordination problem posed by the score.

We then studied 4 groups of novices where the intervening practice between MG trials was « the grid game », the GIG based on turn taking introduced above. This time, coordination (measured as synchronization) did not uniformly increase in the second round of the MG game. Participants reported that they felt the need of a leader making propositions for collective movement to be possible, and that shared leadership was difficult to envisage or comprehend. Instead of the continuously synchronized movements observed in the second MG above, novice participants took turns in proposing movements and responding to others'. The unexpected difference between the two versions of the experiment could have been due to the level of expertise (experts vs. novices) or to the nature of the intervening improvisation practice. While the shared paper movement could have 'primed' synchronicity and shape preservation as a mirroring strategy, the Grid Game gig could have 'primed' alternating leadership and responding to the propositions of others. In subsequent work (not reported here) we tried to experimentally tease apart these two explanations using different scores of music improvisation as intervention between two sessions of MG, with both expert and novice improvisers (Buchkowski, 2018).

Given the subjective reports of turn taking, we annotated moments of movement propositions and responses from the videos of the MG sessions. Overall, the promptness to respond to other's propositions correlated with (self reported) cognitive empathy. This highlights again the link between relational kinematic patterns and socio-affiliative meaningfulness of making time together. The annotation approach permitted us to identify another dimension of the turn taking strategy: participants tended to respond more to the person standing in front of them and tended to report feeling closer to that person. We propose that this splitting of the groups into dyads was a means to simplify the temporal coordination problem (as can be observed in large ensembles of collective free music improvisation ; Goupil et al., 2021).

These results, albeit collected on a small population, highlight the importance of integrating both qualitative analyses (from both player and spectator perspectives) and quantitative measures. Small runs and short interventions were sufficient to reveal a variety of possible strategies that are related to the participants' skills and the constraints of the tasks. The MG thus appears well-suited for the study of intersubjective attunement in a way that can integrate first-person and third-person perspectives.

In Himberg et al. (2018) the analysis conducted on video annotations took individual propositions as a point of departure and group coordination as the consequently emergent structure. This helps identify the timescale at which a turn taking logic was occurring: the average lags between successive propositions were rather short (average median length: 2.65 +- 0.50 seconds). Nonetheless, what these analyses fail at exploring is the possibility of an higher-level form of group coordination (i.e. the structuration of the performance at longer timescales). In musical collective free improvisation, structuration emerges without any prescription and exhibits

a typical segmental form: a succession of collective sequences containing a plurality of individual actions yet stable features (Cannone & Garnier, 2015). In the MG data discussed above, the mere visualization of raw time series (Figure 1a) suffices to suggest a collective organization at a slower timescale (with stable kinematic features such as movement velocity or frequency). In contrast, they hardly reveal the structure of the multiple segments of individual propositions collective sequences encompass. Moreover, the potentially complex coordination of movement at multiple timescales is lacking from the original analyses, which only evaluated the sharing of temporality in terms of synchronicity (cross-correlations and lags between annotated propositions and responses).

To address the theoretical perspective of this chapter, we returned to the kinematic data from the 4 groups of novices discussed above and conducted further exploratory analyses: 1) identify the presence of collective sequences and estimate their approximate duration 2) quantify group coordination at multiple timescales. Below we present the method used to tackle each of these issues, then we present and discuss the results.

To gauge the presence of collective sequences, we quantified group attunement in terms of movements' frequency content. We performed wavelet transforms on the finger's velocity to track the temporal evolution of kinematics in the frequency domain. For each 1-second window, we performed correlation between the power spectra of each pair of partners and averaged them in each group to obtain a time series of the evolution of frequency attunement within the group. To gauge how long sequences that are stable in terms of frequency sharing last, we computed the autocorrelation of series of local power spectra calculated above for each participant and averaged the resulting functions at the group level.

To approach coordination from a multiscale perspective, we computed the power spectra of each finger velocity's time series and cross-spectral coherence between each pair of partners (using semi-overlapping windows of 2048 points - about 20 seconds -). We averaged the amount of coherence obtained for all the pairs within each group in various frequency bands (the same as in the Articulations GIG). To evaluate the significance of the results, we assembled virtual groups by shuffling the members of the original groups and compared them with the real groups at all frequency bands.

The time series of group (frequency) attunement generally display plateaus of high coordination during which the frequency composition of the partners' movements highly converge. As can be seen from the example in figure 1b, these plateaus are separated by abrupt drops that reflect unstable transitions toward a novel phase of collective coordination. When we average the auto-correlation functions obtained for each participant and trials, we observe a first minimum at a lag of about 12 seconds (figure 1c). This is the timescale under the limit of which the frequency content of movements tends to have a certain stability. The clarity of collectively structured sequences varied amongst groups, but they all displayed such an organization to some degree, which is strikingly similar to the « segmental form » observed in musical CI (Goupil et al., 2021). The alternance between plateaus of high attunement and quick drop of coordination matches the opposition between « phases of synchrony » and « phases of

diachrony » that we previously described in musical CI as the core dialectic of group creativity (Laroche et Kaddouch, 2015 ; see also Dahan et al., 2016, in the context of the MG). Stable collective sequences can thus emerge at their own timescale during spontaneous, unscripted and non-verbal interactions between multiple agents, similarly to musical improvisation (Cannone & Garnier, 2015) but in our case during movement practices participants are not familiar with.

Individual power spectra display a very low number of frequency peaks. They are coherent among the members of each group, but they can differ a lot between groups (figure 1d). This identifies group choices or collectively emerging preferences that are recurrently exploited in the course of interactions. This further supports the idea that collective dynamics provide the context within which individual and interactional patterns take shape. T-tests revealed significantly more coherence in real groups than in virtual groups in the 0.15-1Hz and the 1-4Hz frequency bands, and a marginally significant increased coherence in the 4-7Hz and the 7-10Hz frequency bands (which might be due to the low number of groups available for the comparison ; see Table 2). The difference was thus more important in the lowest frequencies, reflecting the recurrent choice of rather slow oscillations to drive movement, as revealed in the qualitative examination of the power spectrum (figure 1d). It might also reflect the slowly evolving dynamics of the intersubjective organization of movement. However, differences occurred at high frequencies as well, which resonates, albeit in a different range, with the findings that during the synchronization of slow movements, rapid chunks of submovements are interpersonally coordinated as well (Tomassini et al., under review).

CONCLUSION

In this chapter, we considered time from the perspective of the experiencing interacting agents: a complex and multiscale phenomenon that is inherent to the dynamics that constitute our living, yet that is lived relationally in our active coupling with the world. In short, temporality is a fundamental dimension of our sense-making activities. In our social existence, sense-making is participatory : by coupling through bodily interactions, we play a role in each other's experiences and, as such, we make time together, and we shape it in a way that matters to us affectively. Collective improvisation stands out as the very practice of participatory time-making and therefore it offers a privileged window to tackle its phenomenon. We thus designed group improvisation games (GIGs) that allow us both to experience and to experiment on the processes that underlie participatory time-making. Despite the variety of their forms, these GIGs commonly highlight the complex yet spontaneous way with which we tend to coordinate the temporality of our behaviors in the course of our interactions, as well as the link between such coordination and socio-affective and semiotic/meaning-making processes. We thus give shape to time together in a way that is meaningful for our relationship. Beyond a mere alignment of lived and acted temporalities, what the study of interactional time reveals is the emergence of temporalities that are proper to the interaction, such as group timing preferences and structuration of collective sequences whose organization span slower timescales than those of individual actions.

TABLES

HEAD	0.15-1 Hz	1-4 Hz	4-7 Hz	7-10 Hz
p-value	<u>0.017</u>	<u>0.059</u>	0.576	0.445
z	2.3953	1.8857	0.561	0.7645
HANDS				
p-value	0.285	<u>0.007</u>	<u>0.059</u>	0.285
z	1.0703	2.7011	1.8577	1.0703

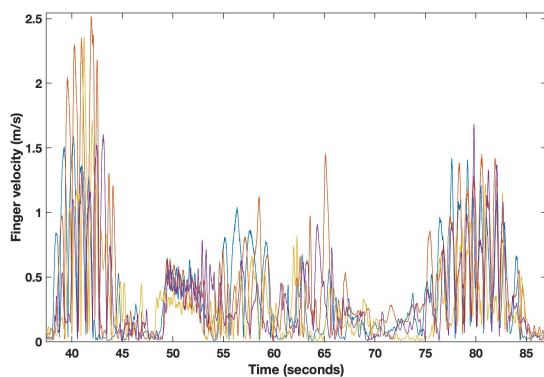
Table 1. Results of the Wilcoxon signed-rank test comparing presence versus absence of one's avatar visual feedback in Articulations.

	0.15-1 Hz	1-4 Hz	4-7 Hz	7-10 Hz
p-value	<u>0.0394</u>	<u>0.006</u>	<u>.055</u>	<u>.053</u>
t(3)	3.5046	7.1589	3.0478	3.1173

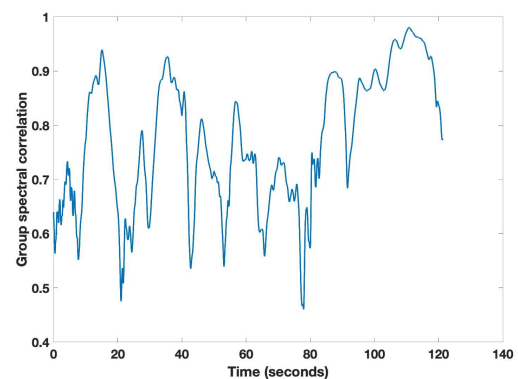
Table 2. Results of the t-test comparing cross-spectral coherence in real and virtual groups in the 4-person Mirror Game.

FIGURES

1a)



1b)



1c)

1d)

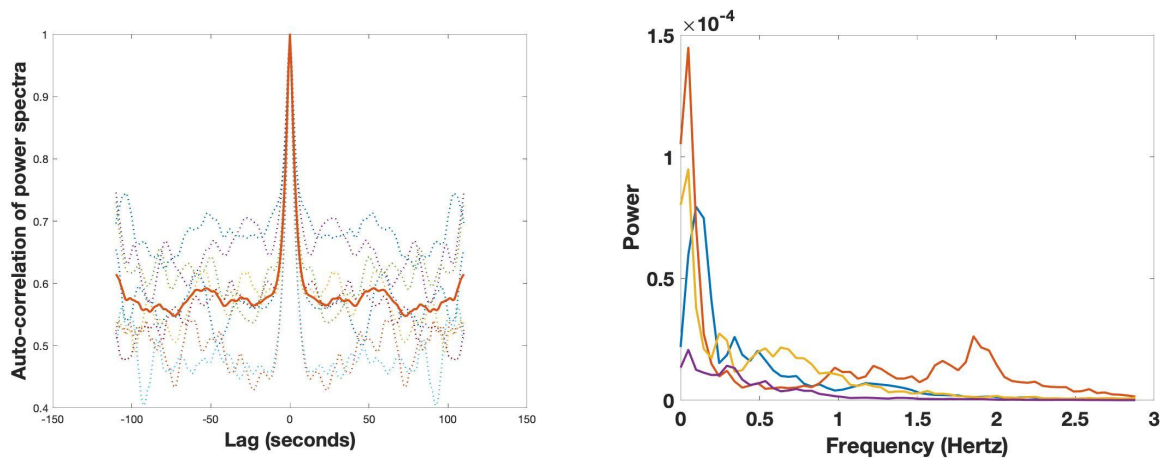


Figure 1a) Excerpt of the finger velocity raw time series of all the 4 participants of one group. The game is marked by a succession of more or less stable collective sequences wherein movements have a rather specific amplitude, velocity and shape, in between of which movements are smaller, as if they were waiting for an impulse to enter a new sequence.

Figure 1b) Time series of group attunement in terms of spectral correlation (same group and trial as in 1a). Peaks and more or less stable plateaus of high attunement of about a dozen of seconds on average succeed to each other, separated by abrupt drops of coordination.

Figure 1c) Auto-correlation of the local power spectra. The highlighted function represents the overall average auto-correlation while the dashed function each represents the average function of one trial of one group. Correlation coefficients quickly drop for 11 seconds, on average, then more slowly until they reach a minimum at a lag of 22 seconds. The 11 seconds lag reflects well the approximate length of collective sequences identifiable in visually inspected plots such as in figure 1b.

Figure 1d) Power spectrum averaged for each of the 4 groups (second game). The plot of each group displays a few distinct frequency peaks or bands that characterize the singularity of their collective activity.

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TH: Could there be a more “unified” structure for discussing each game? Something that builds up from individual dynamics to joint ones?

I also think the grid game could merit its own discussion in terms of the interpersonal timing. The observation that the rules are generated not just by those who propose them but by those who observe and accept/deny them, and the general sense-making in such under-constrained environment, by at least building a common timeframe and set of temporal expectations, matching movement speeds and intensities, while the actions themselves lack meaning (until they start to gain meaning by means of repetition and interrelatedness). I find the concept of “comedic timing” very important in this context, you’d often get away with an “outrageous” action by timing it well, e.g. throwing other players’ pieces off the grid or introducing totally new things. (of course, no data on anything about this, but there were also some efforts on trying to look at the timings of novel ideas in four-way finger dance that we recorded in Aalto, and looking at them in the context of linguistics, ie. if the proposals were accepted or delayedly accepted or rejected)

LEFTOVERS :

Similarly, the coordination of intentions to consolidate versus to change an ongoing sequence within a large ensemble of music improvisers has an oscillatory form (Goupil et al., 2020). Highest peaks of intentions’ attunement were observed in the middle of stable collective sequences, and drops reflecting moments where intentions are the least attuned were observed during transitions between sequences. These observations all show that groups of people can spontaneously structure collective sequences from local interactions and without verbal mediation or pre-specified scripts (Cannone), and that this collective organization unfold at a timescale of its own (compared to the timescale at which individuals take turn in leading and proposing). Our own observations add that this can be achieved during movement practices with which novices are not familiar with.

To investigate the emergence of collective sequences, we first quantified group coordination in terms of the sharing of movements’ frequency content. To do so, we performed wavelet transforms on the finger’s velocity time series, a technique that allows us to track the temporal evolution of kinematics in the frequency domain (Issartel et al., 20XX). In other words, this permits us to obtain a map, similar to a musical score to some extent, that indicates which periodicities compose movements at successive points in time (i.e. a different power spectrum for every slice of time). We then extracted the average power spectra of successive, non-overlapping windows of one second. For each of these windows, we performed pairwise correlation between each partners’ local power spectra, giving us an index of local frequency matching. Finally, in each window we averaged correlation coefficients found in all the pairs of a group. This provides us with a time series that represents the evolution of frequency attunement within the group (figure 1B). To gauge how long stable sequences last (in terms of frequency

content), we performed autocorrelation on the series of local power spectra calculated above for each participant. Then, we averaged autocorrelation functions found for all participants at the group level. Finally, to approach coordination from a multiscale perspective, we computed windowed power spectrum over each time series of finger velocity (using Welch function in successive windows of 1024 data points, i.e. about 10 seconds). From this, we computed cross-spectral coherence between each pair of partners (using similar parameters as above). Then we averaged the amount of coherence obtained for all the pairs within each group at different frequency bands (between 0.15 et 1Hz for the first band, then by 1Hz-wide bands between 1 and 10 HZ, TO BE CORRECTED : I SIMPLIFIED IN 4 BANDS LIKE ARTICULATIONS). In short, this gives us an index of group coordination at different timescales. To evaluate the significance of the results,, we assembled virtual groups by shuffling the members of the original groups (participants 1 of each group forming one group, and so on). Then, we averaged the two trials of each group, and compared the real and the virtual group at all frequency bands (Table 1).

- 1) We design GIGs iteratively through the experiences that stem from our own collective practices; a protocol is valid if it elicited the experiential feature we interrogate conceptually.
- 2) GIGs are open-ended: they don't have fully pre-specified goals, in contrast to empirical tasks that expect certain normative performances or results. This helps focusing attention on the process itself (of moving and interacting), thereby enriching experiences and facilitating subsequent verbal reports.
- 3) GIGs accept a plurality of solutions, which stimulates both divergent thinking (envisioning and exploring a variety of potential strategies) and convergent thinking (making choices and coordinating them, which implicates attention to others and our interactions with them). It allows us to track the two main « coordination problems » that Cannone (XX) identified in group improvisation : consolidation (of an identifiable idea) and articulation (changing toward a new idea).
- 4) GIGs incite interactive generativity, where simple individual actions allow to generate more complex collective forms.
- 5) GIGs are mainly for groups beyond the dyad, which further diminishes the importance of individuality and emphasizes de-centralized group properties.
- 6) GIGS should allow us to track first-person experiences and measure bodily activity, to help these perspectives to dialogue with each other.
- 7) GIGs allow novices in dance or improvisation (and if possible children and neuro-diverse individuals) to take part, by keeping a balance between the richness of experiences that comes from artistic practices and a format amenable to scientific analysis.
- 8) GIGs should elicit clear shifts in experiences and behavior, helping us bridge a gap between the affective reception of particular moments of interaction and the quantifiable dynamics that underlie them.
- 9) GIGs avoid verbal communication as much as possible in order to focus on the relationality between movements as an operating source of interaction.

10) GIGs should be engaging, so as to foster the richness of interaction and their associated affective experiences.

This chart is not entirely rigid, but rather constitutes an ecology of guidelines. Depending on the question of interest, some GIGs emphasize some principles, sometimes at the expense of others.