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# Cognition and Segmentation In Collective Free Improvisation: An Exploratory Study

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## ABSTRACT

Collective Free Improvisation (CFI) is a very challenging form of improvisation. In CFI, improvisers do not use any pre-existing structure (like the standard in straight-ahead jazz), but try anyway to produce together coherent music. This can be seen as a coordination problem: musicians' production must converge to collective sequences, defined as time frames during which each improviser achieves relative stability in his musical output while judging the overall result satisfying. In this paper, we report on an exploratory study made with free improvisers in December 2011 in order to understand the cognition of musicians placed in a CFI context, in particular the role played by their representations of the improvisation under different type of sequences into the explanation of both their behaviors and the coordination success or failure.

## I. INTRODUCTION

We propose here a study of musical cognition in the context of Collective Free Improvisation (CFI). CFI is a musical phenomenon produced by at least two persons, improvising simultaneously and freely, *i.e.*, trying to leave undecided every compositional aspects until the very moment of the performance. Pressing (1984) defined CFI as a referent-free improvisation. A referent is an underlying formal scheme or guiding image specific to a given piece, used by the improviser to facilitate the generation and editing of improvised behavior on an intermediate time scale. In CFI, as opposed to referent-based improvisation (like straightforward jazz), there is no founding act (like the common choice of a standard) that confers a given set of musical (or sometimes even extra-musical) data the status of *common knowledge* in a group. Moreover, CFI is often seen by its practitioners as a type of experimental music, in which musicians are trying to avoid *clichés* or too-predictable formulas, rhythms or harmonic progressions : musicians playing CFI often seek for uncharted musical territory.

Free improvisers thus try to satisfy two constraints:

- To achieve and maintain coherence throughout the performance despite the lack of *a priori* collectively agreed-upon structures or abstract schemes.
- To satisfy individual aesthetic preferences, *e.g.* by avoiding “low-complexity regions” (Borgo 2005).

As put by Borgo, musicians in CFI are continuously “surfing the edge of chaos” by “ensuring continual development and excitement” (Borgo 2005) while finding a way to plainly “play together” in the absence of pre-existing common rules, predetermined structures or arrangement, and internal or external conducting. CFI can thus be seen as a typical coordination problem: musicians try to achieve relative stability in their musical outputs, while evaluating the overall result satisfying. When this is collectively achieved during a long enough time frame, it defines a collective sequence.

Collective sequences can be seen as attractors or fixed points in the musical stream. Improvisers try to converge to such a fixed point which is then developed, played with or even negated, until it is finally discarded, which ends the sequence. This “sectional” organization is probably an endogenous feature of CFI (Nunn 1998). Of course, the coordination problem is at its highest difficulty at these very moments of articulation between sequences, when improvisers must pass seamlessly and collectively from one attractor to another, which also often means finding a new organization of the interactions “on the fly”.

In an earlier paper (Canonne & Garnier 2011), we presented a model for CFI, using non-linear dynamics to describe the signal produced by improvisers and the evolution of cognitive parameters labelled *intention* and *objective*. One of the main results of this model was to predict the existence of two types of collective behavior in CFI:

- A stable behavior, where each improviser's signal remains relatively constant: this corresponds to a fixed point in the phase space of the system and can be seen as a collective sequence.
- An oscillating behavior, which corresponds to a limit cycle in our system. It can be seen as a phase of discoordination or, minimally, as a phase without fixed attractors.

More generally, it showed that a self-organization of the collective signal was possible, in spite of the absence of *a priori* structures: a given CFI can manifest, sometimes quite prominently, an emergent structure.

This paper's goal is to present some findings on this organization process by examining real-life CFI, paying attention to the following questions:

- How improvisers temporally segment a given CFI?
- Do they agree on the segmentation?
- Do they make a distinction between different types of sequences?
- How is made the articulation between successive sequences?
- What are the strategies used by musicians to ensure coordination?
- What is the role of shared representations in the emergence of collective sequences?

## II. DESCRIPTION OF THE STUDY

The experimental setting we used was similar to the one proposed in Sansom (1997). We asked groups of 2 to 4 musicians to improvise freely together for 10 minutes. They were then immediately isolated in separated cabins where they could listen to the improvisation's recording. They were given two tasks:

- To comment on the improvisation from their own point of view, focusing on their own signal, their interaction with the other musicians, their individual decisions, and their overall feeling during that improvisation. They could stop and rewind the recording at any time if they needed to. A few guidelines were provided for the commentary, e.g.: can you point out the moments where you have tried to introduce a new musical idea? Did you have a specific reason for introducing this very musical idea? What did you think of your partners' propositions? Can you point out the moments you liked/disliked?
- To propose a segmentation of the improvisation piece in successive sequences, if possible, and to justify their choice (*i.e.*, which feature(s) they used to determine the transition from one part to another).

Recordings were done in Paris in December 2011. 7 groups were recorded: 1 duo, 1 trio and 5 quartets, with a total of 20 different musicians. Musicians were aged from 22 to 35 years and were all thorough practitioners of free improvisation. Half were graduate students, and half were professional musicians and/or teachers.

The first part of the study is a qualitative one: we wish to describe as precisely as possible the musicians' thoughts during the performance. In this purpose, musicians were asked to avoid *a posteriori* analytic considerations and on the contrary to try to remember what they were thinking *while* they were improvising. Moreover, subjects were asked to be totally honest in the way they restate whatever feelings and appreciations they might have had while improvising. Asking the musicians to listen to and comment the improvisation's recording was just a way for us to gain access to a "photograph", unfortunately reconstructed and biased, of the improviser's mind during the performance.

The second part of the study is more analytic. Our goal was to confront these data to the predictions of our model. In particular, it appeared clearly in our model that the coordination task was the most difficult when players start to change their objectives (*i.e.*, when they introduce a new idea, or change the way they interact with the rest of the group), which often results in a change of the collective behavior. Our hypothesis was that the articulations between the different time segments defined by the musicians would be points of special interest for the study of musicians' cognition in CFI (in terms of strategies, intentions, goals, preferences, representations, *etc*). Moreover, we thought that the behavior of the musicians would depend on how they evaluate and describe the ongoing situation (*i.e.*, if they feel that they were in a phase of coordination or a phase of dis-coordination); and that coordination itself probably depends on the existence of a shared representation of the ongoing situation.

### III. SEGMENTATION AND ARTICULATION

We not only compared together segmentations proposed by musicians from the same group, but compared also the segmentation proposed by a musician with his first-person commentaries. This led us to four observations detailed below.

A: the segmentation appears to be intersubjective. B: a typical sequence length can be extracted. C: there are 4

different kinds of sequences. D: three different cues are used to decipher the transition between consecutive sequences.

#### A. Intersubjectivity in the segmentation

First, we compare the segmentations of an improvisation proposed by the musicians who performed it. In Figure 1 is represented such a segmentation for a quartet. Although musicians proposed different segmentations, we observed that they agree on the roughest one. For example, the euphonium proposed a rough segmentation in 6 sequences, whereas the clarinet proposed a finer segmentation in 12 sequences; nevertheless, within a margin of about 5 to 12s (see the vertical lines in Fig.1), all segmentations match the rougher one. The thick vertical line at time 650s is described in paragraph D.

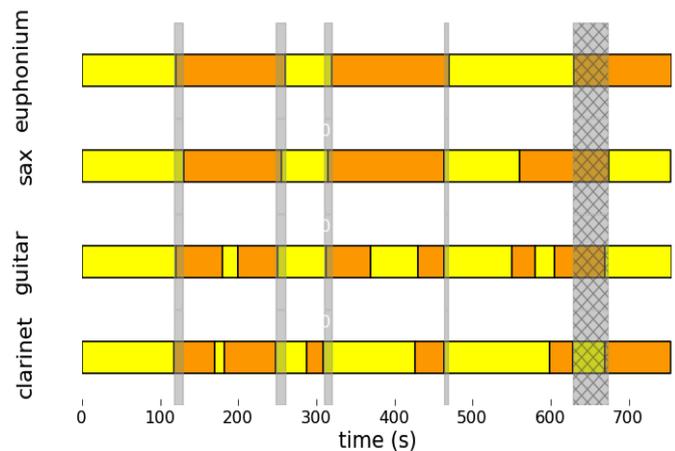


Figure 1. Example of segmentation (arbitrary colors). Thin vertical lines indicates intersubjective transitions, of respective width 11s, 12s, 10s, 5s (from left to right). The thick vertical line of width 44s corresponds to an erratic (unstable and unpleasant) sequence qualitatively undistinguishable from a transition (see text). The improvisation can be heard as Sound Example 7.

#### B. Sequence length

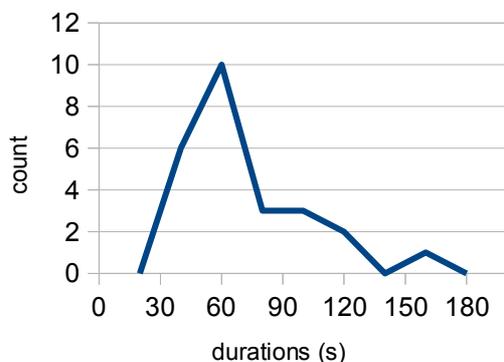
As seen in the previous paragraph, sequence lengths vary from one musician to another. And so they do from one improvisation to the other. Surprisingly, we observed that all sessions were segmented by musicians in sequences of comparable lengths. Results are reported in table 1. The duo session and the trio sessions are perfectly comparable to all quartets sessions.

Table 1. Average sequence duration  $\langle T \rangle$  in seconds and corresponding standard deviation  $\sigma$  in different groups : duo  $N=2$ , trio  $N=3$ , and quartets  $N=4$ .

N	2	3	4
$\langle T \rangle$	71	78	75
$\sigma$	18	39	31

In Fig. 2 is plotted the histogram of sequence lengths, aggregating data from all sessions and musicians. The typical sequence duration (the one with the maximum probability) is 60 seconds, although the average duration is slightly larger (75 seconds), while the standard deviation is about 30 seconds.

It is interesting to note that although musicians were providing possibly very different segmentations of the pieces, including long sequences as seen by the large upper tail of the distribution, a typical sequence length emerges and can be measured. This typical length might be explained by both the fragility of the coordination in CFI and by a lassitude factor (the musicians' tendency to change their proposition after a certain time).



**Figure 2. Histogram of sequence durations, for all improvisations, and all musicians.**

### C. Describing the sequences : partition in 4 species

Commentaries of improvisers on their collective output clearly revealed that they were defining sequences according to two orthogonal criteria : stability (presence of permanent acoustical, musical, gestural or interactional features over a certain laps of time) and desirability (presence of a sustained aesthetic interest over a certain laps of time).

Hence, a musician can perfectly judge a stable sequence uninteresting while an unstable one can be interesting. Coordination is thus non-reducible to the common goal of achieving stability, for example by sharing some acoustical/musical/gestural parameters or by establishing a clear enough interaction pattern. Conversely, unstable or transitory sequences, if maintained long enough (achieving a duration comparable to the one of a stable sequence) can be highly valued by improvisers, probably because it is in these very moments of interpolation, confrontation or suspension that some of the most typical formal features of CFI come in the forefront. Indeed, it is in these very sequences that the *complexity* of CFI is best manifested.

We thus isolated four types of sequences:

1) *Erratic sequence (unstable and uninteresting)*. This is what we call a “phase of dis-coordination”. It can result from multiple reasons (some of which we are discussed below) and it is symptomatic of the following cases: high density of changes in the musical material; conflict between at least two different ideas over a long lap of time; lack of proposition (no musician is willing nor capable of proposing a stable and interesting-enough idea; this is often a result of a certain form of politeness well identified by Siron 2007). We can also note that it is when a musician identified a sequence as “erratic” that we observed a peak in the commentaries’ density: unsurprisingly, when the musicians detect a discrepancy or a significant problem,

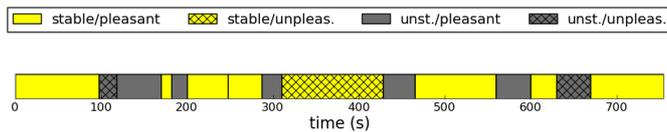
they try to understand why it has arisen and thus spend more time commenting it.

2) *Unstable but interesting (or non-disturbing) sequence*. While not the most common (instability being often associated with dis-coordination by the musicians), some sequences were nevertheless clearly described as both unstable and interesting by the improvisers. We distinguish three different cases:

- the sequence is a long transition, with a sense of progressively *getting somewhere* (in a way, there is a stability or a cohesiveness in this kind of sequence, *i.e.*, a stability in the *process* at work);
- the “indeterminate” nature of the sequence is valued because it generates aesthetic qualities like suspension or fragility: this is however a very delicate balance, which necessitates a full agreement on the evaluations made by the improvisers (otherwise, it can quickly fall into an “erratic” sequence).
- “accepted instability”: improvisers find perfectly normal to encounter instability at certain moments in the improvisation, and thus do not try to prevent voluntarily this instability; rather, they prefer to let things “happen by themselves”. A typical case of such a sequence is the beginning of the improvisation: it seems to be well-accepted that things need a little time to “fall in place”.

3) *Stable but uninteresting sequence*. It happens when the improvisers fall in a “low-complexity region”. There is an attractor, but it is too conventional and makes the musicians unsatisfied. For example, in one of the improvisation (a trio with saxophone, euphonium and percussions, see Sound Example 1), the musicians find themselves playing a quasi-jazz, groove-oriented sequence (with the percussion landing the pulse, the euphonium doing a sort of *ostinato*, and the saxophone acting as the soloist). There is thus a clear attractor for the musicians (with a sense of pulsation and shared motives), who all maintain a relative stability in their own signal for at least two minutes. Nevertheless, all the musicians agree that this sequence is both too connoted and not enough inspired to acquire an interest of its own. This explains why an improviser can sometimes want to *create* instability, by problematizing a texture he finds too simple; as put by Sawyer (2003), improvisation is sometimes more a “problem-finding” situation than a “problem-solving” one.

4) *Stable and interesting sequence*. This is what we have labelled “collective sequence” and it is the paradigmatic case of coordination in CFI. In such a sequence, improvisers find an point of convergence that allow each musician to develop with confidence his signal while maintaining a certain level of excitement in the performance. Two factors can end such a sequence: the lassitude of one or more of the improvisers, who find the need for change and introduce an unilateral interruption; or the chaotic aspect of CFI, by which the accumulation of small variations (resulting from the improvisers’ development of their own signal) finally produce a significant collective deviation, even if nobody wanted to quit the current sequence (*i.e.*, the collective organization is quite often emergent over the individual decisions).



**Figure 3. More detailed segmentation of the same improvisation as in Fig. 2, but extracted from the spoken commentaries of clarinet player.**

As an example, we give in Figure 3 the segmentation of an improvisation (the one of Figure 2) into the different types of sequences proposed above, as given by one of the musicians in his commentaries. We notice that the number of sequences is larger, so the segmentation is more detailed. It is interesting to note that the musician defined as erratic the sequence of length 44s represented in Figure 1 as a wide transition (hatched vertical line at time 650s), thus supporting the inter-objectivity of the segmentation.

#### D. Articulation between sequences

Nunn (1998) has presented an extensive typology of the different types of transitions between two parts of an improvisation. While finding this typology very informative, Canonne (2010) has argued that a transition often becomes a sequence of its own in CFI, which is supported by our study: musicians described some transitions as autonomous parts. Therefore, he proposed to focus instead on the notion of “articulation”, either between two sequences or between a sequence and a transition.

Answers provided by the subjects suggest that three major kinds of cue are used to detect a change of sequence, both from an “insider” and an “outsider” perspective (*i.e.*, both in the first and in the second part of our study).

1) *Monitoring the signal's energy profile: cadential movements and silences.* The simplest articulation one can consider is the juxtaposition of two sequences. Although it is common and easy to perform in solo improvisation, it is much more difficult to do in CFI. In all our experimental recordings, juxtaposition happens only in particular situations, when all musicians have identified without any ambiguity that the ongoing sequence has come to its “natural” ending. To gain this knowledge, musicians monitor the variations of the energy level of the performance: a large deceleration and/or a diminuendo, a sustained period of low-density signals and, of course, collective silence. Such situations happened at least once in every recording. We can interpret this by saying that it is extremely likely that, over a ten minutes-period of CFI, improvisers are not able to prevent a severe decrease in the energy profile; *i.e.*, the collective energy seems to entirely dissipate over a certain amount of time, which characterizes the fragility of CFI's situations. We also noted that in the segmentation task, these moments were always used to define an articulation between two sequences. One must also note that in these situations, although the musicians know that an articulation must be made (if not, the improvisation will end), it may not be easy to do. In fact, once the musical stream has been interrupted, it is often difficult to continue in a way that does not sound artificial (see Sound Example 2, where, after a silence, improvisers seem to struggle to find a new stable idea). Hence, silences

are not only clear clues helping in the identification of possible articulation for the musicians, but also sources of problems in the formal task inherent to CFI.

2) *Detection of Salient Events.* Examining the game-theoretical literature on pure coordination situations, Canonne (in press) has shown the general importance of saliency in CFI and the ability of expert free improvisers to single out salient musical events in order to face CFI's coordination problem. In a general context where unpredictability is at its foremost (due to the absence of common referent and to the non-idiomatic way of improvising), it is extremely important for improvisers to be able to create (or to discover) points of convergent expectations in order to create some stability in the flux of musical events. A salient event, by its very saliency, is *transparent*: it can procure something like common knowledge in the group (everyone has noticed a peculiar event and everyone supposes that everyone else has noticed it). This is probably the reason why such events play a very important role in the articulation of sequences, *i.e.*, in operating a significant change in the collective behavior. Some events will thus “hook” all the players together and produce either abrupt or gradual changes. We observed four different types of such events: a contrasting event inside a given context (e.g. : a new timbre, a clear pitch in an otherwise noisy environment); an “accident”, either at the individual level (a sound with an attack which was ill-mastered) or at the collective level (a sudden unison or an unexpected simultaneous attack); an event with an “immediate” saliency (a loud and/or high-pitched sound: as Juslin (2009) puts it, “Brainstem reflex refers to a process whereby an emotion is induced by music because one or more fundamental characteristics of the music are taken by the brainstem to signal a potentially important and urgent event. All other things being equal, sounds that are sudden, loud, dissonant, or feature fast temporal patterns induce arousal in the listener”, p. 136); the entrance of a previously silent player in the improvisation, or conversely, the disappearance of a player. The following examples taken from our recordings were all noticed and reported without ambiguities by the musicians in their commentaries: a *sul ponticello* cello's harmonic that provokes a progressive stabilization on sustained textures (Sound Example 3); an entrance of saxophone that precipitates the end of the improvisation (Sound Example 4); an encounter between contrabass and clarinet on a common E, that brings a new sequence in crescendo (Sound Example 5); or a sudden nail-*glissando* on a low piano string, that stops the group for just a quick respiration, before a new sequence actually begins (Sound Example 6).

3) *Detection of Transitory zones.* Improvisers sometimes identify a time interval --- a “zone” --- where the music is changing and a new sequence finally emerges, but they can't precisely locate it in time. Moreover, this zone is often too short or too heteroclitic to be identified by the musicians as an autonomous sequence. In such a situation, we usually observed that the musicians placed the mark between these two parts at various places on a given laps of time. The reason is that there is a chain of causes and effects taking

place at that moment, and the musicians choose whatever event seems relevant for themselves to propose a sharp date. This accumulation of variations is symptomatic of CFI and defines one of its features: the musicians display a very high sensitivity to the others signal's variation. In a situation where there is no common referent, musicians tend to give each other proof that they are interacting together: and for an improviser, the better way to acknowledge that a change in a co-improviser's signal has been perceived is to introduce a variation in his own signal. Figure 1 gives an example of such a case (the entire improvisation can be heard on Sound Example 7): in this improvisation, the guitarist and the clarinetist are playing alone together from 7'40"; the tubist and the saxophonist remained silent during this duo, because they thought the improvisation would finish at the beginning of the guitar/clarinet duo, and they could not figure out a way to "come back" into the music. At 9'10", the guitarist proposes a variation in his electronic texture, in order to "make something happens" (as noted by the guitarist himself). At 9'20", the saxophonist makes windy quasi-flute sounds, which fit nicely with the guitar texture (this articulation is noted by the saxophonist): but it does not change the music dramatically. So at 9'40", he comes back with loud and repeated pitches (this articulation is noted by the tubist). Finally, at 10", the tubist introduces a sustained low-tone pedal that increases the collective tension (noted by the clarinetist). This example also clearly establishes the distinction between a transitory zone and an "erratic" sequence: the erratic (*i.e.*, incoherent and unpleasant) sequence depends on the absence of a common clear direction or the absence of something that "glues together" musicians' outputs, while the transitory sequence depends on the variation frequency observed on a given laps of time. In the example above, the musicians feel that an "erratic" sequence has begun at 10'30" (*i.e.*, after the last variation has been observed) when after a silence, the tubist come back with the same low-tone as before : all other musicians clearly do not know what to do with it (to play the same thing as before or to do something else).

We therefore isolated three main categories of articulation in CFI: cadential articulation (drop in the collective energy), interruptive articulation (use of a salient event) and interpolative articulation (emergence of a transitory zone).

#### IV. COMMUNICATION, IMPROVISERS' STRATEGIES AND SHARED REPRESENTATIONS

When musicians improvise, they tend to distinguish two aspects of a given signal: its acoustic, musical and/or gestural content on the one hand; and its "intentional" content, *i.e.*, what the signal *means*, what it let appear from its producer's intentions and objectives, on the other hand. As such, a great deal of the improvisers' cognitive resources is devoted to an encoding/decoding activity as identified by Pelz-Sherman (1998): the competency of musical agents in an improvised interaction depends on their ability to "convey the semantic intent of their own musical ideas to other performers in real time" and to "make accurate judgements in real time about the

semantic intent of each performer" (p. 127). This "semantic" content can stand for different things which all refer to intentional states, transmitted in or deduced from the signal: the *formal content* (through a given gesture a musician can communicate to his co-improvisers his objective about the current situation's evolution); the *interactional content* (through a given gesture, a musician can communicate to one of his co-improviser's his intention to enter in a certain form of interaction with him); the *evaluative content* (through a given gesture, a musician can communicate to his co-improvisers his evaluation or representation of the prevailing situation); and probably others.

It is this very distinction between musical and intentional contents that makes strategic reasoning crucial in CFI: improvisers make musical decisions because they expect or anticipate some kind of response or reaction from the other improvisers, based on the implied semantic content of their signal.

CFI is what Pelz-Sherman calls *heteroriginal* music, *i.e.*, a form of music where "decisions are made during the performance as the product of the relationships of *multiple agents*" (p. 9). In this kind of music, the *separateness* of the agents makes discrepancies in the situation representations and evaluations, or in the preferences about a given situation's evolution quite likely: one can thus partly relate the success of the musicians coordination to their ability in constructing a shared representation of the improvisation.

We can draw, in this regard, two significant results from our study:

- Musicians use different strategies based on the way they construct their representation of the current situation (*i.e.*, as one of the four types of sequences described above).
- The most patent case of dis-coordination emerges when the musicians have contradictory or quite different representations of a given situation. As such, dis-coordination may be seen as *miscommunication* between improvisers.

##### A. Decisions and Strategies

Not every decision is based on a strategic intention. Most common decisions of a musician are made based on the musical logic (as seen by the musician) of both his individual discourse and the collective result. In this case, the primary focus of the musician is on the musical aspects of his signal, and the way these musical aspects satisfy the requirements of both internal consistency with what has been previously played, and external consistency with what is played concurrently.

Other decisions are based on more cognitive factors, especially the cognitive load (sometimes, an improviser decides to "stop paying attention" to one of the other improvisers because he "can not follow him anymore") and the lassitude (sometimes, an improviser just get bored with his own idea or "does not believe in it anymore" and then decides to do something else).

Nevertheless, it appeared clearly in the commentaries that strategic decisions (decisions made with a specific goal and/or a collective response in mind) were quite frequent. Of course, improvisers use a very large array of strategies in CFI; but the most interesting ones are the "meta-pragmatic strategies";

they result not only in decisions taken for an intended purpose but also in decisions of which the primary motivation is precisely to convey the improviser's intention or representation of the situation. In such situations, the signal is produced primarily for its intentional aspects, and sometimes musical aspects are not even relevant. The purpose of these strategies is essentially to modify the improvisation's interaction pattern or formal contours, either radically or partially.

Here are two examples, taken from our recordings: in one improvisation, the saxophonist noticed that the flutist was not playing for a while; he thus decided to abandon the high-pitched creaking sounds he was producing to play a distinct pitch (a low F), hoping to give the flutist a "passageway" into the interaction. And indeed, the flutist took advantage of the opportunity, and came back into the improvisation, with a whistle-tone that merged beautifully with this low note. But as soon as his goal was accomplished, the saxophonist returned to his high-pitched creaking sounds (Sound example 8), making clear that this distinct pitch was not the beginning of a new idea.

The other example is much more radical: because he was evaluating an ongoing sequence and finding it too long and static, the tuba player suddenly interrupted the improvisation with a loud and strident motif (much like a scream), with the hope for "producing something new". But the three other musicians did not react to this strong interruption even if, as it appeared clearly in the commentaries, they had all understood his intention. The tubist tried again a few seconds later with the same motif: the other musicians were then ready and used his motif as a signal to increase the music's intensity (Sound Example 9). This is also a nice example of the kind of implicit negotiations that can be seen in CFI. Since the original strategy has failed, its meaning has been modified between the first and the second occurrences: the absence of reaction the first time (partly because some musicians did not want to modify their proposition) caused the tuba motif to shift from a clear interruptive signal to a mere stimulation signal. This change of status was obvious in the way the tubist was playing his motif: three short outbursts the first time; a longer and continuous stream the second time, as if it was more a way to enrich the polyphony, by adding a new, contrasting layer, than a way to radically modify the collective organization.

Aside from these meta-pragmatic strategies, we have observed four significant types of strategy used by the musicians in CFI:

1) *Stabilization strategy*. It is certainly the most recurrent type of strategy used by the musicians. This indicates clearly that the stabilization of the improvisation (*i.e.*, finding a way to make all musicians' signals "work together" for a while) is one of the musicians' important goals in CFI. However, this is not surprising if we remember that CFI is "referent-free": achieving formal stability in the absence of a given pre-existing structure is precisely one of CFI's great challenges. In the commentaries, we observed that when a musician describes the sequence as "erratic", "chaotic" or "unstable" he also gives an explicit description of his own reaction and actions in terms of a "stabilization strategy". Two sub-types can be distinguished: the musician simply repeats a pattern, strictly

or with little variations (creating an *ostinato* or a loop), or holds a sound/texture/pitch for a certain time, proposing *de facto* an attractor for the others to join in; or he tries to operate as a mediator between two too heterogeneous ideas presented by other improvisers, thus proposing a possible synthesis and future attractor.

2) *"Wait and see" Strategy*. This can be seen as a variant of the stabilization strategy. It is mainly used by the musicians when they describe the situation as transitory. The musician deliberately stops playing or maintains a very low-information signal, in order to, quoting one commentary, "see where things are going": he is waiting for a new idea to emerge. When musicians are trying to find a new attractor, this strategy can be very helpful to clarify the situation.

3) *"Playing along" strategy*. It appeared clearly in the commentaries that the musicians are fully aware of the fragility of CFI, and the fact that it can "fall apart" so easily. Hence, the cooperative aspect of the interaction always seems to be stronger than its agonistic aspect: it is more important to find a way to play together than to impose a personal and preferred idea. When musicians feel that an idea is not very interesting but can nevertheless work as an attractor, or when they feel that the group is going towards an inevitable direction, musicians generally "play along", *i.e.*, they do their part in the interaction, play what they are implicitly expected to play. There is of course a place for implicit negotiations and confrontations between different propositions, but typically at the beginning of a new sequence. Once the music starts to flow, the negotiation margin quickly decreases. The "playing along" strategy is a way to acknowledge this state of affairs. In such a situation, the musician decides to play his part, but in a minimal way, just enough for the music to continue, but not enough to remain the same for very long.

4) *Densification strategy*. This kind of strategy is typically used by a musician when he described the improvisation as boring, predictable, uninteresting... In such a situation, the musician deliberately creates complexity by adding a new layer in the improvisation. He hopes to provoke a transition, or a crystallization, by the dialectical confrontation of two contrasting elements, of a new, more exciting attractor. A typical example is given by a saxophonist commenting about the beginning of one of the improvisations: "It is my first sound in this improvisation and I think to myself: I'm going to break this situation, which is either too stable or too boring, but for sure without any clear direction. As a consequence, some diversified, non-congruous events start to appear and are added to this continuous texture maintained by the euphonium. In that sense, my intervention was rather successful".

## B. Coordination and shared representations

The fact that improvisers maintain similar representations of a given situation plays a great role in the success of the coordination task. If all improvisers frame a situation as erratic, for example, it will not be long before an attractor appears and a new collective direction emerge. Conversely, an erratic sequence emerge typically when improvisers have very

contrasting representations of the situation. Similarly, a difficult articulation between two sequences often results from different appreciations on the improvisation's formal conduct.

It follows from the commentaries' analysis that three different kind of representations should be distinguished:

- The musicians' representations of a given situation: this includes the aesthetic interest of the situation (is the music good?), its stability/instability (is there a clear attractor?), its directionality/absence of direction (do we know where the music is going? Is it a transition?), its place in the improvisation as a whole (e.g.: can it be seen as a recapitulation of a previous sequence?), its place in the actual sequence (is the sequence already long enough or should it be developed little more?), the way the interaction are structured in it (e.g.: has the saxophonist taken a soloist spot?)...
- The musicians' representations of an other musician intentions and objectives.
- The musicians' representations of team preferences, *i.e.*, of what is best for this particular band he's playing in, given the instruments, the musicians, their various cultural backgrounds, *etc.*

Of course, there are often differences in the first kind of representations, because these representations are build on very individual-specific backgrounds of preferences, past experiences, musical knowledge, *etc.* As for the differences in the second kind of representations, they often result from the inability of the musician to unambiguously convey the intentional content of his signal. Representations of the third kind were less often formulated, but seemed to play a great role in the regulation of improvisers' decisions: indeed, the musicians will shape the coordination problem of CFI according to these representations of team preferences by sharply distinguishing between situations that fit the group well and situations that risk to jeopardize the group. As an example, we can quote a clarinetist at the beginning of his commentaries: "I quickly said to myself that the best thing to do, given that we don't know each other, and given the instrumentation, would be to work on lengthy things, with slowly evolving textures, trying to converge at least on the pitches".

We give below a few examples of the impact of shared representations on the smoothness of the improvisation's collective flow.

1) *Misperceived intention (Sound Example 10)*. In this example, the flutist says that her energetic intervention is designed to produce a quick articulation, and to avoid a collective sagging: the goal is to attract immediately the other musicians with this new proposition. But the other musicians do not perceive that intention: on the contrary, they all consider her intervention as a clear signal for the beginning of a solo. This leads to a literal dead end, manifested by an awkward silence and a few hesitations, before something else is proposed by the percussionist.

2) *Transparent intention (Sound Example 11)*. The percussionist says that his intervention was designed as a cut, to create a sense of synergy. This was clearly perceived as such by the other musicians. One of the musicians evoked the "breaking nature" of the percussion, capable of

provoking such vivid articulations: for him, the intention of the percussion intervention was obvious. And indeed, the resulting collective articulation was efficient and very successful.

3) *Shared formal representations (Sound Example 12)*. Here, all the musicians said that they knew, when this sequence began, that it would probably be the last part of the improvisation. Here are two comments made by different musicians, which are remarkably similar: "It's always very difficult to abandon this kind of proposition. Sometimes, the best way is just to stop!" (Double-bass player); "We know that we are probably coming to an end, because if we continue to push things further, we know that we will arrive to a breaking point, a difficult point: the moment when you need to get out of this thing. And, aside from just stopping the improvisation, it's difficult to do such a thing" (Clarinetist). The musicians are thus all waiting for an "exit point", something that will help them with stopping the improvisation; it is the sudden appearance of higher harmonics in the cello (produced accidentally, according to the cellist) that gives the signal for everyone.

4) *Contrasting evaluations of a given situation (Sound Example 13)*. Here, the evaluation of the situation strongly depends on the musician: "There is a collective rarefaction that I found very interesting. I thought it was a nice moment" (Clarinetist); "It becomes suddenly more pointillistic. There! That's when things are starting to fall apart" (Tubist). The tubist clearly fears the apparition of an erratic sequence, while the others are rather satisfied with the fragile quality of the music. Unsurprisingly, the tubist adopts a stabilization strategy, by introducing a simple *ostinato*. But this signal is not well-accepted by the other musicians, who would have enjoyed maintaining the same atmosphere and are puzzled by the *ostinato*. As a result of this seminal difference of appreciation, the sequence is perceived as rather unpleasant by the musicians, as it is composed of parallel ideas that never really converge. It then takes almost 60 seconds before this initial dissonance is resolved.

It appears on these examples that the emergence of shared representations plays a crucial role in the success of CFI's coordination task. It would certainly be of great interest to use paradigms and results from the field of team cognition and apply them to the case of CFI.

## V. CONCLUSION

This study highlights some essential features of musical cognition in CFI. A significant part of the improvisers' cognitive resources seems to be devoted to the formal problem of CFI: what to play next and what to play together? This double-question is not trivial, and it does not receive easy answers, as testified by the number of erratic or unpleasant sequences identified by the musicians in the analysis of their actual improvisation. Two difficulties come in the forefront: the first one is about establishing and/or identifying an attractor (convergence problem), while the second one is about the transition from one attractor to another (articulation problem). We identified three relevant paths followed by the improvising musicians to cope with these difficulties: the

presence of salient events; the use of strategic reasoning; and the emergence of shared representations. This last aspect opens a promising direction to explore: it should lead to new works in the field of team cognition research.

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