Psychological Research 84 (2020): 1555-1571

DOI: https://doi.org/10.1007/s00426-019-01168-4

Title
Musical Dynamics in Early Triadic Interactions. A Case Study

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Abstract
Research of the last 30 years showed the importance of music for psychological development. Communicative musicality studies described musical organisations in dyadic interactions (adult–baby). However, other perspectives proposed that, from the beginning of life, there are early triadic interactions (adult–object–baby) that should also be analysed. Following previous research, we hypothesised that early triadic interactions have a structured musical organisation. We recorded a 2 month-old child interacting with his mother and an object in their home and performed a microgenetic quantitative–qualitative analysis. Given the child's age, we focused on musical characteristics of the mother's actions. To our knowledge, this is the first study to combine data processing provided by ELAN, Finale, and Matlab-MIRtoolbox. Our analysis shows that the child participates in triadic interactions in which the mother communicates about and through the maraca using musical resources in increasingly complex ways. Musical structuring happens at the intersegment, intrasequence, and intersequence levels, and involves different musical parameters. We suggest musical organisation in early triadic interactions follows a holographic structure in which each piece carries information about dynamic processes of different timescales. Results highlight the importance of considering objects and their uses to better understand early communicative musicality.

Keywords
communicative musicality, early triadic interactions, developmental dynamics, object use, pragmatics of the object.

Acknowledgements
This study was supported by the program for the Training of University Teachers (Formación de Profesorado Universitario – FPU) of the Spanish Ministry of Education, Culture and Sports, to which the first author of the article belongs reference FPU16/05358] and Project EDU2011-27840 (MINECO, Spain).

The authors would like to especially thank Dr. Joanna Rączaszek-Leonardi for her valuable comments on this work, and for suggesting the holographic structure idea that we use here.

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Musical Dynamics in Early Triadic Interactions. A Case Study

Introduction

Music is an essential cultural activity for humans. It is usually defined as the organisation of rhythmic and sonorous events for artistic purposes, under certain aesthetic canons (Benward & Saker, 2015). However, research in cognitive science over the past 30 years has shown that it transcends these limits (Tan, Pfordresher, & Harré, 2017). Music makes up a universal communicative medium that permeates our (inter)actions in the world and contributes to *in*form (that is, to give form) our daily experience (Cross, 2014).

Research on *communicative musicality* (Malloch, 1999; Malloch & Trevarthen, 2009) has shown that music is essential for early psychological development. Communicative musicality refers, according to Trevarthen (2011, 2012), to a neurobiological impulse that drives us to create and share music with others from birth. This impulse would be part of a repertoire of innate human impulses that includes, among others, the impulse to *play* and *story telling* (Trevarthen, 2017), and would allow us to establish synrhythmic regulations with others. This means that, from birth, thanks to this impulse, mother and child can communicate and co-regulate themselves psychologically through musically organised signs (Trevarthen, Aitken, Vandekerckhove, Delafield-Butt, & Nagy, 2006).

It should be noted that, in this research framework, *communicative musicality* has a very precise operational definition. Malloch and Trevarthen (2009, p. 4) identify three core elements that characterise it: *pulse*, *quality*, and *narrative*. While *pulse* refers to regular recurrences of temporal patterns that structure events during interactions, *quality* relates to spectral aspects of sound. For its part, *narrative* is linked to the organisation of

events into temporal units according to pulse and quality resemblances. As for *music,* it is proposed that it can be understood as "a particular drawing-together of the elements of pulse, quality, and narrative - elements that are intrinsic to all human communication" (Malloch, 1999, p. 47).

According to Trevarthen (2015) the communicative musicality of the child generates changes in the semiosis of adults, shaping the motor and sonorous contour of their actions, and favouring a musical social coupling. As Cross (2009) argues, music is part of the human communicative toolkit and a key interactive medium to acquire social skills. In that sense, it seems very likely that the distinctive features of human interaction are rooted in our connection to music (Di Stefano, 2016).

Classic studies on communicative musicality embrace Trevarthen's theory of intersubjectivity (Trevarthen, 1979; Trevarthen & Hubley, 1978). Therefore, they distinguish: (i) a basic, innate, and dyadic communication mode (*primary intersubjectivity*) that would manifest, for example, in neonatal imitation, mother-baby protoconversations and solitary interactions with objects; and (ii) a triadic communication mode (adult-baby-object interactions), called *secondary intersubjectivity*, which would not emerge before 9 or 12 months of age (Trevarthen, 2015). Before secondary intersubjectivity, the child would only relate in dyads, either with people or objects. Consequently, studies on communicative musicality in early childhood have focused on describing and analysing musical organisations that take place within dyadic mother-baby interactions. Some privileged research topics have been:

(i) The musical characteristics of *infant-directed speech* (e.g. timing, rhythmic organisation or acoustic composition), its role as regulator of child's actions and emotional states, and its influence on linguistic development (Fernald, 1989;

Fernald et al., 1989; Keller, Otto, Lamm, Yovsi, & Kärtner, 2008; Malloch, 1999; Miall & Dissanayake, 2003; Papoušek, H., 1996).

(ii) The presence of recurrent musical organisations in babies' vocalisations (Papoušek & Papoušek, 1981).

(iii) The coordination between the corporal movements of the mother and the baby, the degree of *interactive synchrony* that is established between them (Condon and Sander, 1974), and their analysis in terms of correspondences, rhythmic patterns and dynamic contours of action (Español, 2010; Español & Shifres, 2015; Martínez & Español, 2009; Stern, Beebe, Jaffe, & Bennet, 1977).

(iv) The expressive characteristics of adults' spontaneous singing to the child (Trehub, Unyk, & Trainor, 1993) and its modifications in cases of adult mental illness (e.g. depression) (Robb, 1999).

(v) The effects of musical therapeutic intervention on fostering social engagement in dyadic interactions (Malloch et al., 2012).

However, the proposal that children begin to communicate with others in a triadic fashion towards the end of the first year of life (Bates, Camaioni, & Volterra, 1975; Tomasello, 2004, 2008) has problems. For example, it has been pointed out, from the *pragmatics of the object*, that the pure diadicity supposed by primary intersubjectivity does not exist: early social interactions take place, often, around materiality. Objects are part of interactions from the beginning. And this is so because, even when the child cannot blend in the same communicative act one object and another person, he is placed by others in meaning-loaded material scenarios (Rodríguez, 2012; Rodríguez et al., 2018). Considering the cultural semiotic complexity of the material world and its role in early communicative exchanges would blur the sharp split between primary and secondary

intersubjectivity. Therefore, it is highly likely that this stance is relevant to describe the gradual construction of intentional behaviours during ontogenesis.

Others have questioned the nativist emphasis of Trevarthen's theory and its dependence on phylogenetic and biological factors (Gergely & Watson, 1999; Rodríguez, 2006). While our biology might well be *socially oriented* (Wallon, 1942/1970), it is unlikely that cultural cognition is anchored in an innate self-to-other representation (Trevarthen & Aitken, 1994) or in natural experience-seeking motor patterns directed to others (first) and objects (after) (Trevarthen, 2009). This would mean, paradoxically, that *joint* attention depends on *individual* dispositions. From birth, adults exert great influence on children's cognitive development through communicative mediators (e.g. movements, emotional expressions, gestures, object uses demonstrations and vocalisations). A more comprehensive stance should consider the asymmetry of adult-child relationships and the effects of adult mediation on children's social development.

Connecting both criticisms, some have proposed that *early triadic interactions* exist from the beginning of life (Costall, 2013; De Schuymer, De Groote, Striano, Stahl, & Roeyers, 2011; Fogel, 1993; Striano & Stahl, 2005). In these interactions, the initiative is not of the child but of the adult who intentionally meets the child and the world in a communicative act. If babies communicate it is not because they have innate social abilities or because they express fully formed intentions, but because adults attribute intentions to them. For this reason, we have claimed elsewhere that the first intentions are borrowed (Rodríguez, Benassi, Estrada, & Alessandroni, 2017). And since, from early on, children are immersed as active *participants* (Rossmanith, Costall, Reichelt, Lopez, & Reddy, 2014; Rossmanith & Reddy, 2016) in niches of interaction where people use objects as communicative vehicles, the intentional loan occurs *through* and *about* objects (Rodríguez, 2006; Rodríguez & Moro, 2008).

This approach coincides with the proposal of *dynamic systems* for the cultural study of interactions and their constitutive role for development (De Jaegher, Di Paolo, & Gallagher, 2010). Interactions progressively coordinate, giving rise to systems of dynamic, open, and changing forces (Holt, Fogel, & Wood, 1998; Hsu & Fogel, 2003). Some have also highlighted the need to investigate how adults integrate and structure the affective and behavioural responses of children through socialisation practices (Köster, Cavalcante, Vera Cruz de Carvalho, Dôgo Resende, & Kärtner, 2016). Thanks to systems of constraints emerging in situated interactions (such as social settings and everyday routines) (Rączaszek-Leonardi, Debska, & Sochanowicz, 2014), adults introduce children to cultural patterns. This results in cultural-specific developmental pathways with normative force that promote certain experiences and forms of behaviour while restricting others (Kärtner, 2015, 2018).

One of the advantages of the dynamic perspective is that it does not analyse interactions as a by-product of individual contributions guided by *top-down processes*, but considering *bottom-up interactive processes* emerging in dynamics. Thanks to *participation* in shared events (Brinck, Reddy, & Zahavi, 2017), individual behaviours are shaped. And this is not capricious but, usually, responds to structured meaningful wholes in which actions have causal consequences (Rączaszek-Leonardi, Nomikou, & Rohlfing, 2013).

Another advantage is that it embraces a functional and multilevel stance. For instance, Rączaszek-Leonardi (2010) argues that since one important function of language is inter-individual coordination, its investigation cannot do without inter-individual variables (i.e., considering language pragmatics leads to a non-individualist analysis of how dynamic forces coming from multiple timescales organise). Nomikou, Leonardi, Rohlfing, and Rączaszek-Leonardi (2016) have also studied the development of gaze

dynamics showing how interactive structures emerge from links between timescales of real-time adjustments and cumulative interactive experiences.

In this article, we argue that studies on communicative musicality can benefit if they consider both the existence of early triadic interactions and the dynamic perspective for the study of psychological development. This would enable the analysis of the multilevel dynamics of communicative musical exchanges and the way they unfold within early triadic interactions.

In two previous studies (Moreno-Núñez, Rodríguez, & Del Olmo, 2015, 2017) we explored, within triadic interactions, the longitudinal evolution of some rhythmic, sonorous, and melodic components associated to object uses. These components ease interactions allowing the adult to segment the world for the child and include him into action. Some of the first baby-adult shared meanings are built *on* and *through* objects, thanks to the integration of musical components in *distant* and *immediate demonstrations of object uses*. We found that from 2 months of age children respond to musical components by paying attention and answering adults' proposals through action. Children progressively get involved in niches of joint action where they learn the cultural uses of objects and, at 4 months of age, they already perform proto-canonical uses of objects (i.e. shaking a maraca in an elementary way) that exhibit certain musical organisation.

However, despite having identified some communicative mediators that adults put into play in early triadic interactions (e.g. *demonstrations of use* or *ostensive gestures* -showing and giving-), we have not analysed their musical characteristics. Based on this, we conducted a descriptive exploratory study with the following objectives: (i) to carry out a dynamic qualitative-quantitative analysis of an early triadic interaction (adult-child-object); (ii) to find out if it exhibits musical components and their eventual organisation; (iii) if so, to describe the structural and dynamic characteristics of the musical organisation

underlying the triadic interaction. In agreement with previous operational definitions of *music* and *communicative musicality* (see Malloch, 1999; Malloch & Trevarthen, 2009), when we refer to *music* we allude to the organisation of the rhythmic, sonorous and melodic components of events that take place within interactions (e.g. communicative mediators) into emergent and meaningful patterns.

Findings from this study have the potential to inform the theoretical debate about communicative musical exchanges in early triadic interactions, an issue often neglected in previous investigations. In addition, this study contributes to enrich the methodological literature by proposing a novel pragmatic, functional and ecological approach. By drawing on different software and including complementary analytical procedures, this article proposes a new kind of qualitative and quantitative analysis. Last, our findings might be of interest for psychological frameworks interested in the development of interactions and social cognition in early childhood, as they may contribute, for instance, to improving parenting practices, especially those related to parent-child communication and semiotic mediation.

Method

Participants and recording procedures

We recorded a non-participant observation (Miller, 2017) of a two-month-old child interacting with his mother and an object (a maraca) in his home in Madrid, during 5 minutes and 27 seconds. Written informed consent was obtained. We used a JVC Everio Model GZ-HM310 camera. This recording is part of a larger longitudinal study in which we observed 6 children interacting with their mothers and a maraca in their homes at 2, 3, and 4 months of age (see Moreno-Núñez et al., 2017). So, this is a case study with a multivariate and cross-sectional methodological design.

Before starting the recording, the child was placed by his mother in a comfortable position. We gave the mother the maraca and instructed her to play with the child as she would normally do. We did not provide instructions on how to use the object, to leave participants to engage through their own strategies. This ensured that interactive interchanges remained as spontaneous as possible.

Materials

The maraca (see Table 1) was designed for children in their first year of age. It is easy to grasp for children due to its dimensions and weight. In addition, its cultural function involves rhythmic-sonorous uses. Based on previous results (Moreno-Núñez et al., 2015, 2017), we predicted this could promote triadic interactions and the adult performance of rhythmic-sonorous communicative actions related to the use of the maraca.

Table 1. Description of the maraca used in our study

Object	Object being used	Physical properties
		Heigh: 12.5 cm. Width: 5 cm. Depth: 5 cm. Weight: 40 g.

Analyses of data

Because our study aimed to analyse the musical characteristics of an early triadic interaction, we first performed a viewing and a microgenetic qualitative-quantitative analysis of the video to find interactive exchanges exhibiting musical components (rhythmic, sonorous, and melodic). To do this, we codified behaviours of the mother and

the child within second-by-second data frames using ELAN[1] (Version 5.2, Lausberg & Sloetjes, 2009) and the procedure described by Rodríguez and Moro (1999). The coding categories correspond to those of previous studies carried out from the theoretical approach of the *pragmatics of the object* (see Table 2). The qualitative information allowed for the examination of how the musical parameters were organized within intentional frames of interaction led by the adult, where objects were enacted as complex cultural referents.

After this first analysis we segmented and extracted, with Adobe Premier Pro CC2017 (Version 21), 5 interactive sequences (S1-S5) in which musical components had special relevance. For each of these sequences, we obtained the audio track using Adobe Audition Pro CC2017 (Version 21) and transcribed it using Finale (Version 25.5), a music notation software. After that, we processed audio tracks in Matlab 2017b (Version 9.3), using 9 mathematical functions of MIRtoolbox (Version 1.7; Lartillot, Toiviainen, & Eerola, 2008), a computer tool for extracting musical features from audio files. The MIRtoolbox functions we used were *miraudio, mirframe, mirenvelope, mirpeaks, mirspectrum, mirautocor, mirtempo, mirpulseclarity,* and *mirsimatrix*. The utility of each of these functions can be seen in Table 3. For each track and each function, we got continuous scores (intra-frame every 500ms) and central tendency descriptive statistics. Then, we exported both groups of scores for conversion into graphic format with Adobe Illustrator Pro CC2017 (Version 21).

The quantitative analysis of scores focused on the comparison of continuous scores and central tendency statistics, both at the intra and intersequence level. Following these comparison, we looked for emergent musical patterns (i.e. whenever we found

[1] Max Planck Institute of Psycholinguistics, The Language Archive, Nijmegen, the Netherlands. URL: http://tla.mpi.nl/tools/tla-tools/elan/.

relationships of regularity, proportionality, recurrency, repetition, or variation among musical characteristics of interaction). Last, we analysed the characteristics of the action of the mother and the baby. We paid special attention to (i) the reiteration of musical components of interaction, (ii) the reiteration of the organisational structure of musical components of interaction, and (iii) the dynamic variation of musical organisation throughout the 5 interactive sequences (microgenetic approach).

Table 2. Observation categories

Children	Adults
Attention. The child's visual activity toward: The object The adult The adult's action	-
Uses of objects Non-canonical uses: Uses of objects according to what they physically allow and not according to its cultural function (e.g., sucking the maraca). Proto-canonical uses: Uses more directed than the non-canonical ones. They announce the appearance of canonical uses (e.g., attempting to grasp the maraca; shaking the maraca in an elemental way). Canonical uses: Uses of objects according to their cultural-defined function (e.g., shaking the maraca).	*Rhythmic-sonorous demonstrations* Performances of conventional rhythmic-sonorous uses of the object directed toward the child (e.g., shaking the maraca). Distant: Demonstrations of use made from a distance (e.g., playing the maraca). Immediate: Demonstrations of use introduced through (joint) actions involving the child's body (e.g., playing the maraca on the child's body; putting the maraca on the child's hand and moving it).
Ostensive gestures Gestures where the child "shows" the object to himself to explore it.	*Ostensive gestures* Ostensive gesture: Gestures involving an object to draw the attention of the child (e.g., showing or giving the maraca) Rhythmic-ostensive gesture: Ostensive gestures that exhibit rhythmic and sonorous characteristics (e.g., isochronous organisations of movements).
Vocalisations Vocal sounds produced by the child.	*Language, vocalisations, and psalmody* Words and vocal sounds produced by the adult, both with the articulation style of the spoken voice and of psalmody (i.e., with a monotonous tone).

Table 3. Description of MIRtoolbox functions used in the study

MIRtoolbox function	Description of its effect
miraudio	Loading, transformating, displaying, and performing operations on the audio waveform of an input audio file
mirframe	Creating short-term windows that move chronologically along the temporal signal in order to take into account the dynamic evolution of musical features
mirenvelope	Computing the envelope of an audio waveform, showing the global outer shape of the signal
mirpeaks	Detecting peaks or important local maxima of an input audio file
mirspectrum	Decomposing a signal along frequencies using a Fast Fourier Transform to highlight the repartition of the amplitude of the frequencies
mirautocor	Evaluating periodicities in signals by looking at local correlation between samples
mirtempo	Estimating the tempo of an input by detecting periodicities from the event detection curve
mirpulseclarity	Estimating the rhythmic clarity, indicating the strength of the beats estimated by *mirtempo* function
mirsimatrix	Computing the similarity matrix resulting from the mutual comparison between each possible frame analysis of an input

This is the first study in developmental psychology to use this microgenetic qualitative-quantitative analysis that combines the data processing potential provided by ELAN, Finale, Matlab and MIRtoolbox, and Adobe Suite (R) software. We could not find in the literature another study using this analytical approach.

Results

In the following subsections, we advance our most relevant results. At the time of observation, the child was two months old and his action was limited. Therefore, the description of interactive musical resources focuses mainly on the mother's actions. Quantitative data that was not essential for describing interactions and their musical organisation is not included in this article. Table 4 describes the main actions of the mother and the child for each sequence.

Table 4. Mother's and child's main actions for each sequence (S1-S5)

S1		Duration: Summary of the interaction:	7 seconds [00:21 - 00:28] The mother (M) has the maraca in her hand. She performs a *distant rhythmic-sonorous demonstration* for the child (C) shaking the maraca without stoping. M moves the maraca transversally from the midline of C's body to its left side. C gaze-follows the movement of the maraca while waiving his left arm. M accompanies him by saying: "Hey, that is over there… ¡Very well!".
S2		Duration: Summary of the interaction:	7 seconds [00:36 - 00:43] M performs three *immediate rhythmic-sonorous demonstrations* for C, putting the macara in his left hand and shaking it. Demonstrations are separated by action pauses. While performing the demonstrations M says: "Ahh… ¡Hala!… What is that?". After that, M caresses the left cheek of C with the maraca.
S3		Duration: Summary of the interaction:	9 seconds [01:21 - 01:30] M places the maraca in C's hand setting his fingers to make sure he is holding it properly. She says: "Pick it up… Pick it up strong or it will fall". M performs two *immediate rhythmic-sonorous demonstrations* for C. She combines demonstrations with rhythmic vocalisations, using the phonetic cells /ti/ and /ki/.
S4		Duration: Summary of the interaction:	6 seconds [02:51 - 02:57] M hides the maraca behind her back and tells C: "Look for it…Ahh". Then, she performs a *distant rhythmic-sonorous demonstration* for C shaking the maraca up and down. This demonstration has seven one-shaking short segments that are isochronous and separated from each other. She accompanies the rhythm by iteratively uttering the name of the shared object ("Maraca, maraca…") with a vocal style that recalls psalmody.
S5		Duration: Summary of the interaction:	6 seconds [03:56 - 04:02] While saying "Take maraca, maraca…" with psalmodic voice, M takes the child's foot and moves it rhythmically up and down. At the same time, she performs a 4 second *distant rhythmic-sonorous demonstration.* Then, M removes the maraca from C's visual field and stares at him.

Sequence 1 (S1): A rudimentary musical organisation

In this sequence, the mother (M) starts a triadic interaction by introducing, between herself and the child (C) the maraca we provided for the investigation. M introduces it through a *distant rhythmic-sonorous demonstration* (dRSD) (she shakes the maraca, without stopping, holding it by the handle, with the head facing down). From the first moment, the maraca captures C's attention and functions as an instrument of communication. Therefore, during the whole dRSD, C follows the maraca with his gaze, even when M moves it transversely from the midline of the body of C towards its left side. As others have argued, this behaviour is an important indicator because, in interactive contexts, children use gaze as a tool to get into communicative exchanges (Csibra, 2010; Filipi, 2009) and adults act setting the pace for the organisation of gaze (Nomikou et al., 2016).

Additionally, when C follows the path of the maraca, M makes a positive evaluation saying: "Hey, that is over there ... Very well!". However, the musical structure of the interaction is very weak. The dRSD has no pauses, accents, rhythmic variations or intensity fluctuations: it forms a non-segmented continuum. Thus, it is not possible to establish a tempo or a stable metric structure (for example, a musical bar) underlying M's actions.

Sequence 2 (S2): Immediate demonstrations, pauses, and rhythmic organisations

In S1 M uses a dRSD to capture C's attention and communicate with him. In this sequence, however, M performs three *immediate rhythmic-sonorous demonstrations* (iRSDs) (i.e., M shows C how to rhythmically use the maraca by placing it in his left hand and waving his hand). This choice has important consequences. On the one hand, it allows M to act as an ambassador of the material world by incorporating the maraca into the

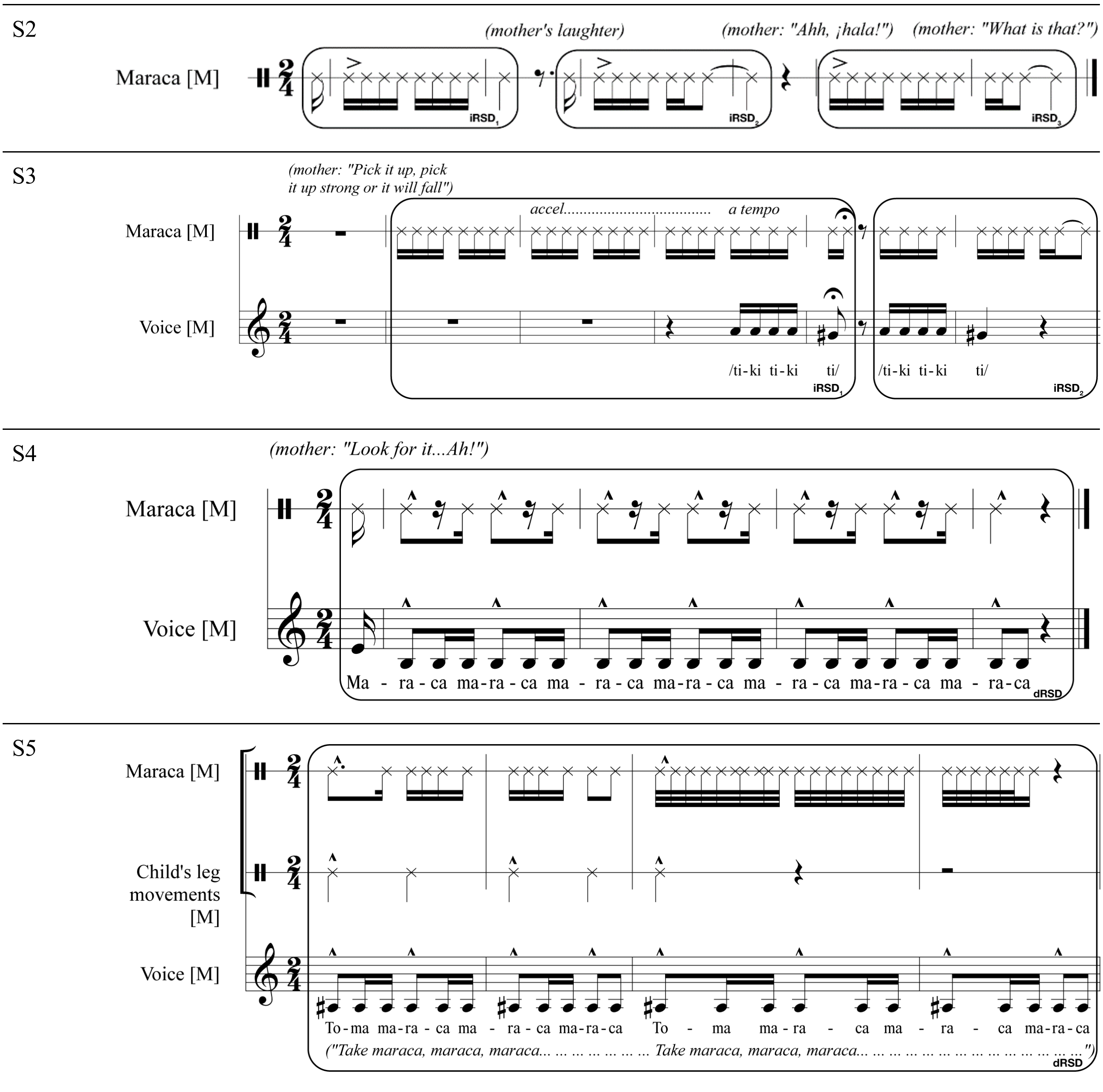
perceptual and enactive field of C. C will not only see M acting on the maraca, but will act *with* it (*joint action*), and will perceive through his own body the sensations associated with the use of the maraca.

On the other hand, the direct nature of the demonstrations allows M to introduce C into a niche of cultural agency at a developmental time in which C cannot use the maraca by himself. By guiding the child in a direct way when using the maraca (i.e. intervening on his body dynamics), M aligns C's action with the use she would perform with the maraca according to the public norms of use it has in our culture (i.e., the maraca should be shaken by holding it by the handle, with the head up, moving it to one side and the other). As we have stated elsewhere (Moreno-Núñez et al., 2015, 2017; Rodríguez et al., 2017, 2018), this loan of intentionality that goes from the adult to the child is characteristic of early triadic interactions.

In this sequence, the iRSDs are different since there are action pauses between them. In the context of the musical analysis we are proposing, these are *musical pauses*. The three demonstrations have between 8 and 11 events (musical attacks), follow a stable 2/4 musical bar, and have a recurrent main rhythmic cell composed of four semiquavers. Each iRSD features slight accents. The first two demonstrations have a musical accent in their second sound event, while the third demonstration has an accent in its first sound event. Since the three accents coincide with the first time (strong time) of the musical bars, we could confirm a stable underlying metric structure. Thus, the non-accentuation of the first event of demonstrations 1 and 2 is consistent, because it corresponds to the *levare* of each rhythmic motif (see Table 5). Regarding the temporal dimension, the three iRSDs have very similar durations ($iRSD_1$=1.06s, $iRSD_2$=1.01s, $iRSD_3$=1.23s*;* $\Delta_{iRSDs1\text{-}3}$=.22s). This contributes to unify the set of iRSDs, endowing the musical organisation with greater

coherence and cohesion. Finally, the pauses between the three iRSDs do not have, in this case, same durations ($Pause_1$=.89s, $Pause_2$=1.89s).

Table 5. Encoding of sequences in musical notation (S2-S5)



Sequence 3 (S3): Tempi variations, vocal patterns, and semiotic stelae

In line with the interactive dynamics of S2, here M appeals again to iRSDs as communicative mediators. She places the maraca in C's hand arranging his fingers

carefully to make sure he is holding it properly. Then, M says: "Pick it up ... Pick it up strong or it will fall" and makes two iRSDs.

The first iRSD has a duration of .86s and has two well-differentiated parts. The first part involves, as in S2, M shaking the maraca to one side and to the other (right and left), according to the cultural norms of use of the object. Its main and recurrent rhythmic pattern coincides with the pattern observed in S1 (four semiquavers). However, unlike S2, this first iRSD fragment exhibits tempo changes. In the beginning, the first fragment of the iRSD has a tempo of 127.3bpm that increases steadily until reaching a tempo of 184.4bpm. This progressive increase in tempo is coincident with the expressive musical resource known as an *accelerando*. In the second fragment of the first iRSD, the tempo remains stable, but there is something new: M uses her voice to produce a rhythmic pattern congruent with the use of the maraca (metric level of the subdivision of the pulse) that alternates between two phonetic cells (/ti/ and /ki/). Also, the vocal pattern involves two pitches (A4 and G#4) whose use follows the logic of the underlying metric structure: the first pitch is used in the four sound events that make up the *levare* time of the rhythmic pattern, and the second pitch in the longer sound that occupies the strong time of the next beat of the pattern. This longer sound coincides with the end of the iRSD (see Table 5).

The second iRSD has a duration of 1.29s. It involves the coordinated production of rhythm with the maraca and the voice. Again, we see the alternation between the phonetic cells /ti/ and /ki/ and the use of the pitches A4 and G#4. The musical analysis shows a decrease in tempo between the second segment of the previous iRSD and this iRSD. Now the tempo is 126.7bpm ($\Delta tempo_{iRSD1[SEGM2]\text{-}iRSD2}$=57.7bpm). This tempo change could be interpreted as the return of M to the first tempo of S3, given the minuscule difference between that tempo and this one ($\Delta tempo_{iRSD1[SEGM1]\text{-}iRSD2}$=.6bpm). Interestingly, the duration of the pause that separates the first and second iRSDs is identical to the

duration of $iRSD_2$ (see Graphic 1). This makes it possible to hypothesise, retrospectively, that the tempo variation was organising the mother's action from the beginning of the pause and not from the beginning of $iRSD_2$. Despite the tempo change, the fragments of iRSDs featuring two musical lines (maraca and voice) (i.e. segment 2 of $iRSD_1$ and $iRSD_2$) are analogous in their temporal extension. This conclusion is based on the fact that the *tempo*duration* relationship has, for both moments, virtually identical values ($tempo*duration_{iRSD_1[SEGM2]}$=164.12, $tempo*duration_{iRSD_2}$=163.74; $\Delta tempo*duration_{iRSD_1[SEGM2]\text{-}iRSD_2}$=.28).

It is relevant to highlight three issues. First, both at the end of $iRSD_1$ and of $iRSD_2$ we observed a lag between the end of the rhythmic motifs of the maraca and the voice. In $iRSD_1$, the rhythm performed with the maraca lasts a semiquaver more than the rhythm performed with the voice. In $iRSD_2$, the rhythm performed with the maraca lasts almost one beat beyond the vocal rhythm. Although the coordination between both lines of the musical system (maraca and voice) is not total, this could be evidence of an outline of inter-line coordination. Second, M organises every action resorting, always, to the combination of *two* elements: two iRSDs, two spatial areas in the transverse axis of movement (right-left), two *tempi*, two phonetic cells, two heights, and two musical lines (maraca and voice). In other words, the organisation of the action follows a multilevel binary logic that does not seem to be fortuitous. Third, here we can see, for the first time, the redundancy of information between different semiotic systems. This is a semiotic phenomenon we called *stelae* (Rodríguez, 2006, p.145). Thus, for example, when performed together, the rhythmic pattern of the maraca matches the rhythmic pattern of the voice, and this coincidence is perceptible to the child at the auditory, visual, and proprioceptive levels (given that RSDs are immediate). This combination of coincident

semiotic information could highlight for the child the organisational structure of M's actions.

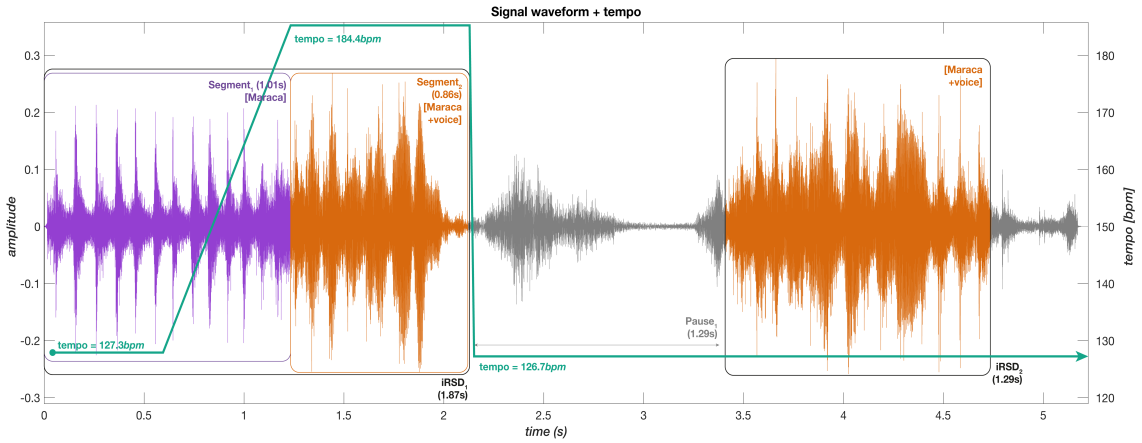


Figure 1. *S3 Signal waveform with RSD segmentations and tempo analysis*

Sequence 4 (S4): Intensity variations and rhythmic elaborations

S4 has two different moments. First, M hides the maraca behind her back, and invites C to look for it through the semiotic system of the language ("Look for it ... Ahh"). Then, she places the maraca again between her and C, and performs a dRSD that, like iRSDs of S3, has two musical lines (maraca and voice). This dRSD is composed of seven one-shaking short segments. The musical analysis reveals a stable metric structure underlying the entire dRSD coinciding with a 2/4 bar. Each segment of the dRSD has a duration equivalent to that of a crotchet. In turn, each segment of the vocal line is composed of three sound events (semiquaver-quaver-semiquaver) on which M articulates the sounds /ma/, /ra/, and /ka/, which, together, make up the word "maraca". As for the maraca line, each segment includes two sound events identical to the first two events of the vocal line, besides a semiquaver silence. In both lines, segments are isochronous with each other.

Both in the vocal line and in the line of the maraca, the second event of each segment is markedly accentuated (i.e. it presents a peak of intensity congruent with the expressive musical resource called *marcato*). The acoustic effect of the accentuation increases because of its application on the long value of the musical motif. With the maraca, the reinforcement is even greater due to the presence of a silence after each accent (see Table 5). The *mirpulseclarity* analysis for the lines of the maraca and of the voice shows that the rhythmic adjustment between both lines is absolute. This shows the great precision with which M combines musical resources.

As in S3, the vocal line has two different pitches (E4-B3). However, the first pitch is only used in the first attack of the first segment of the dRSD. The pitch of the other sound events of the vocal line is B3. Therefore, the voice recalls the musical characteristics of a psalmody. This pitch stability could allow M to put in the foreground the rhythmic dimension and its structural complexity (regularity, accents, and silences).

Regarding the analysis of intersegment variables, two aspects stand out. First, the segments have very similar durations ($duration_{max}$=.47s, $duration_{min}$=.34s; $\Delta_{duration}$=.13s). Although the small differences between segments indicate the existence of microtiming variations, they are not qualitatively relevant. As in S3, the analysis of the relationship tempo*duration gives, for all the segments, virtually identical values. This allows us to conclude that they are analogous in terms of structure (tempo*duration relationship for segments 1 to 7 ranges from 59.97 to 60; $\Delta tempo*duration_{dRSD[SEGM1-7]}$=.03). This makes it possible and relevant to calculate the average tempo for the entire dRSD (141.8bpm) (see Graphic 2).

Second, between the first and the last segment intensity reduces progressively. As the music analysis shows, the average root mean square (RMS) energy decreases as the different segments of the dRSD occur ($RMSenergy_{max}$=.18:, $RMSenergy_{min}$=.07;

$\Delta_{RMSenergy}$=.11) (see Graphic 3). Although this variation cannot be formalised by appealing to a linear function, it does show the organisation that M makes of the intensity inside of the dRSD. So in this sequence M keeps stable the rhythmic patterns both in the line of the maraca and in the vocal line, and she reiterates the use of phonetic cells in the vocal line. However, this time, she introduces a novel progressive and sustained variation in the intensity. This variation is not present in previous sequences.

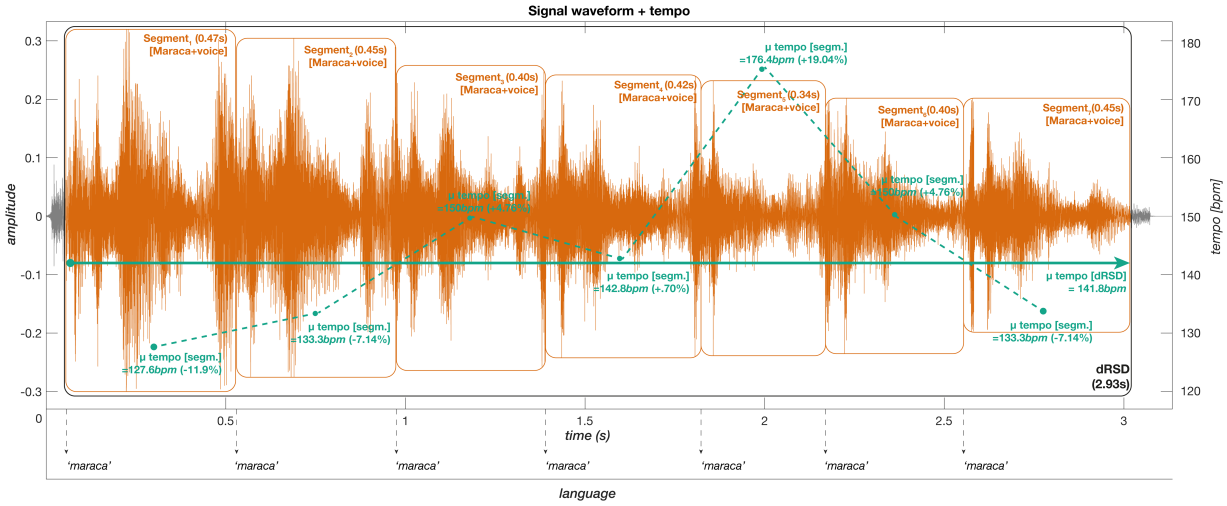


Figure 2. *S4 Signal waveform with RSD segmentations and tempo analysis*

Sequence 5 (S5): A multilevel and complex musical organisation

This sequence has the highest degree of musical complexity. M starts making a dRSD with the maraca and her voice, but this time she adds to the repertoire of musical resources the movements of the right leg of the child that she produces with her left hand. Like in the preceding sequences, the entire musical system of S5 has a metric structure congruent with a stable 2/4 bar. However, the rhythmic organisation of the maraca is much more complex.

In the maraca line M combines three different metric levels: that of the division of the main pulse (quavers), that of the subdivision of the main pulse (semiquavers), and that

of the division of the subdivision of the main pulse (demisemiquaver). In the vocal line, M combines rhythmic values corresponding to the levels of the division and the subdivision of the main pulse (quavers and semiquavers). Meanwhile, the movements of the child's leg coincide with the level of the main pulse (crotchets) (see Table 5). This is the only musical line in which this metric level stands out. The musical events of the three lines can be described as two musical segments of two measures each. In the vocal line, both segments are identical, while in the other lines, the second segment has variations. Regarding its temporal extension, both segments have very similar durations ($duration_{SEGM1}$=2.1s, $duration_{SEGM2}$=2.05s; $\Delta_{duration}$=.05s).

Once again, we find accents (*marcato*) congruent with the strong and semi-strong beats of the different bars included in the dRSD, in all the musical lines. Interestingly, accents are distributed in such a way that, if the lines of the maraca, the movements of the child's leg, and the voice are considered in sequence, each sequence has twice as many accents as the preceding sequence. Thus, the line of the maraca includes a *marcato* at the beginning of each segment (first time of bars 1 and 3), the line of the movements of the child's leg has a *marcato* at the beginning of each bar (except for bar 4, in which no sound events were recorded), and the vocal line presents a *marcato* in each beat. Here we are facing another case of *semiotic stelae*, because the information referring to the rhythmic structure of the interaction is being communicated through three different modalities: visual (M's movements), auditory (dRSD and voice) and proprioceptive (C's leg movements made by M).

The vocal line is an elaboration of the motif of S4. Here we find a longer motif with eleven sound events (three groups of a quaver and two semiquavers followed by two quavers) on which M says "take maraca, maraca, maraca" (see Table 5). This rhythmic

pattern is repeated twice inside the dRSD. Vocal pitches remain stable (A#3) also exhibiting the articulatory style of psalmody.

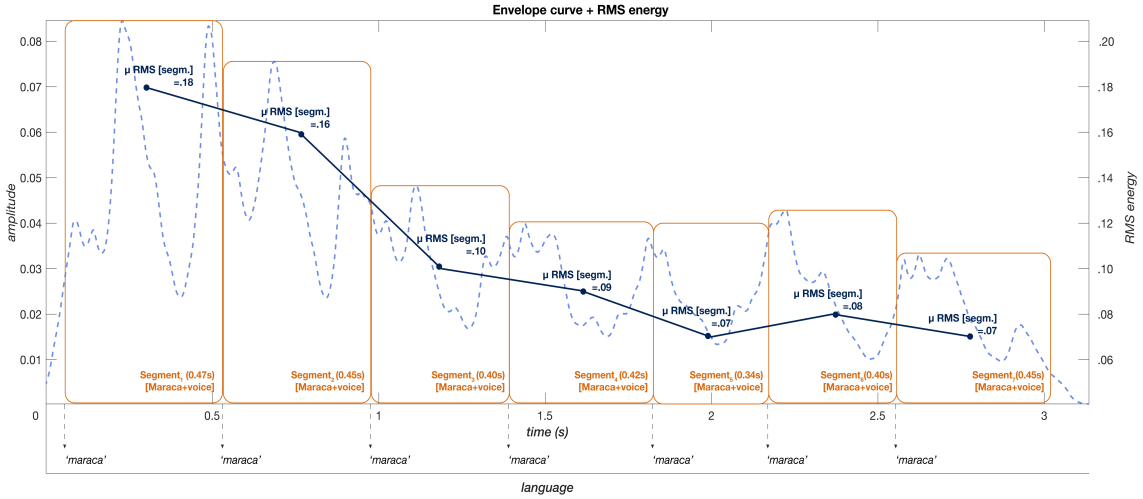


Figure 3. *S4 envelope curve and RMS energy analysis*

Within this dRSD we could not find relevant intensity variations, but we found a decrease of the tempo with respect to the one used by M in previous sequences. Here the average tempo is 102bpm, almost 40bpm lower than the S4 tempo and also less than the S3 *tempi* (184.4bpm and 126.7bpm). We suggest that this tempo decrease could be proportional to the increase in the interactive musical complexity: M would descend the tempo to help C understand the complex structuring of musical resources.

Discussion and conclusions

Our first aim in this article was to find out if within five sequences of an early triadic interaction (child [0;2(3)][2]-mother-maraca) there were musical components such as those studied in dyadic interactions from the perspective of communicative musicality. If this was possible, our second aim was to describe the musical organisation of these

[2] Chronological age: [years; months (days)].

components (internal structuring) and their dynamic variations (microgenetic variations of internal structuring).

Our analysis shows that at two months of age C takes part in early triadic interactions in which M communicates *about* and *through* the maraca. There are multiple evidences to support this. One of them is found in S1, when C follows with his gaze the dRSD that M performs for him. Besides, M tries to introduce C into public niches of agency very actively. Pauses between RSDs are examples of this: they introduce the child into turn-based exchanges before the child can take initiatives of action consistent with this structure. These turn-based exchanges are characteristic of our culture, and are at the basis of other activities (e.g. some games or linguistic exchanges). Here, turns do not organise around words, but around RSDs that M offers C, that is, around a material referent and M's action on it. This is very relevant, since it shows that objects are much more than collections of perceptible physical attributes: they are part of intersubjective meaning networks from the beginning of life (Moro, 2015, 2016; Rodríguez et al., 2018; Rodríguez & Moro, 1991; Rodriguez & Moro, 2008).

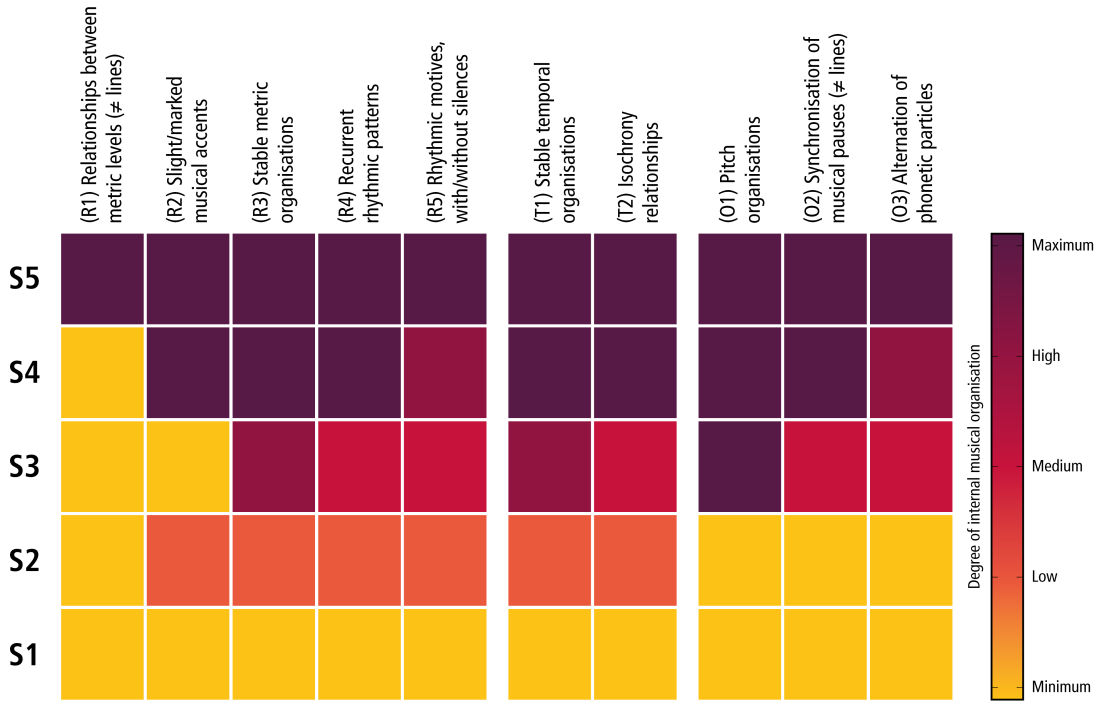


Figure 4. *Heatmap chart representing the degree of S1-S5 internal musical organisation*

Our analysis also shows that M uses a large amount of musical resources. Sequence by sequence, she structures these resources in different, increasingly richer and complex ways. Between S1 and S5 M composes a musical elaboration *on* and *through* the maraca, using RSDs of the maraca (both distant and immediate), her voice, and the movement of the child's leg. Within sequences we found musical components belonging to three musical dimensions: *rhythmic-metric structure* (R), *temporal organisation* (T), and *other musical parameters* (O). The musical components we found were: (R1) hierarchical relationships between different metric levels in different musical lines (see S5); (R2) slight or marked musical accents; (R3) stable metric organisations (i.e. bars); (R4) recurring rhythmic patterns within each musical line or between musical lines; (R5) rhythmic cells and motifs, with and without systematic use of silences; (T1) stable

temporal organisations (i.e. stable *tempi*) and their variations, both sudden and progressive (i.e. sudden changes of tempo, *accelerandi*); (T2) isochrony relationships between different RSDs, pauses, parts or musical segments; (O1) organisations of pitches and variations of them (in the vocal line); (O2) sketches of synchronisation of musical pauses between different musical lines; and (O3) alternating phonetic cells. It should be noted that these musical dimensions converge with the core elements of communicative musicality proposed by Malloch and Trevarthen (2009). This is interesting as long as it shows certain similarities in the analysis of musical characteristics of dyadic and triadic interactions in early childhood. Specifically, R2-5 would be linked to *pulse*, O1 and O3 to *quality*, and R1, T1-2, and O2 to *narrative.*

The horizontal reading of Graphic 4 shows the degrees of internal musical organisation for each sequence. These degrees are qualitative and relative, as we defined them according to the results presented in the preceding section. For example, S1 has the minimum degree of musical organisation since musical components of all dimensions are less structured than in other sequences. The vertical reading of Graphic 4 shows that internal musical organisation increases as S1-S5 occur. This suggests that besides musical organisation at the *intrasequence level* there is musical organisation at the *intersequence level*. Thus, throughout the interaction we witness the microgenetic enrichment of the initial musical organisation (S1). For instance, for rhythmic cells and motifs (R5), the graph shows that from S1 to S5, the degree or organisation increases (S1=minimum, S2=low, S3=intermediate, S4=high, S5=maximum). This implies that, as the interactive dynamics unfold, M uses rhythmic cells and motifs with and without silences more systematically. We found this increasing microgenetic complexity for each musical component, with different degrees of progressiveness (some musical components become complex more gradually than others).

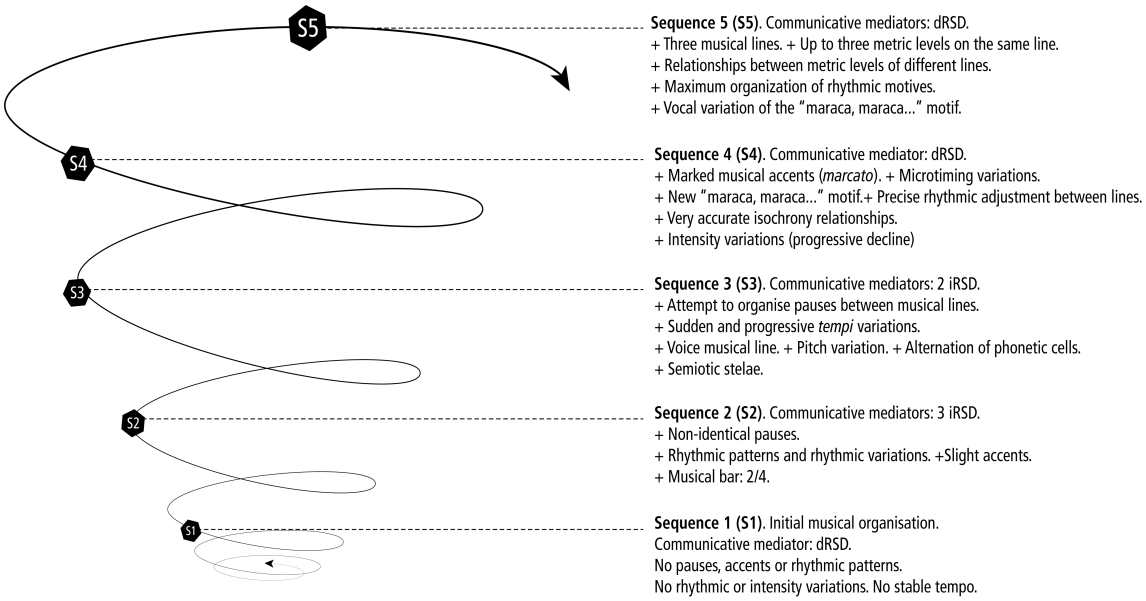


Figure 5. *Microgenetic unfolding of musical structure between S1 and S5*

Graphic 5 shows the details of the progressive musical organisation between S1 and S5 and what are the novelties for each sequence. We found that musical organisation becomes more complex by three ways: (i) adding new musical components, (ii) structuring previous musical components in a different way, and (iii) alternating one or another interactive resource.

The rhythmic dimension is a good example of the first strategy. Although S1 does not have pauses, accents or rhythmic patterns, S2 has all these elements, as well as a stable bar of 2/4. S3 presents an attempt to organise breaks between musical lines and S4 involves *marcati*, a new rhythmic motif, precise isochrony relationships, and precise rhythmic adjustments between lines. S5 features up to three metric levels per musical line and connections between metric levels of different musical lines. Other examples of (i) are the introduction of stelae (S3) and variations of intensity (S4).

The intersequence increasing complexity for the same musical component is an example of the second strategy. For example, between S2 and S5 rhythmic patterns become more structured and isochronous, and between S4 and S5 M elaborates the vocal motif "maraca, maraca ..." (S4) varying it in its metric, rhythmic and phonetic structure (S5).

Finally, we can see alternation of interactive resources in M's choices of communicative mediators of interactions. If at the intrasequence level we find alternating phonetic particles (S3), at the intersequence level we see alternation in the RSDs M uses. Thus, in S1 M uses a dRSD, in S2 and S3 iRSDs, and in S4 and S5 dRSDs again. As we have stated above and in previous research, this variation is not fortuitous, but linked to the co-regulation of action between the mother and the child and the promotion of child's agency according to cultural norms. A new situation revealed by the musical analysis is that the use of iRSDs and dRSDs could be linked to the characteristics of the interaction's musical organisation. The change of the dRSD (in S1) for the iRSDs (in S2 and S3) seeks to capture the child's attention, to include him in the action, and to link him with the cultural uses of the maraca. But the return to dRSDs (in S4 and S5) seems to be related to the growing musical complexity that unfolds in the interaction. Thus, the analysis suggests that the introduction in higher levels of musical organisation is key in the structuring of the action. It would have been complex for M to perform an iRSD while deploying a musical organisation of three different lines with interline metric relationships (S5) with the maraca, her voice, and the movements of the child's leg. Our analysis suggests that as the musical organisation becomes more complex, M strives to make it understandable for C. In this fashion, the tempo of S5 (102bpm, the lowest of all sequences) could be thought of as a strategy for C to grasp the great complexity of the musical organisation.

It is important to notice that the musical elaboration happens in a total time of 4 minutes, within an interaction of 5 minutes and 27 seconds. This becomes amazing if considered along with the enormous complexity of the organisation of musical components. Our methodological approach reveals that combining qualitative microgenetic analysis and quantitative analysis has great potential to describe in detail the dynamics of communicative musicality within the early triadic interactions. This approach allows to bring together numerical information (musical parameters) and qualitative information about M's educational influence through different semiotic systems and C's answers in interaction. M's action, C's action, the maraca, and the interactive musical components, together with the multidirectional connections between them, make up a system whose description is crucial to understand the dynamics of the triadic interaction.

The analysis of other videos of our broader longitudinal study suggest that in triadic interactions occurring when C is older the musical components identified in this study are present. Also, there is congruence in relationships between musical components, in varying degrees. Other videos of children interacting with their mothers and the maraca show coincidences between their musical organisation and that of the video analysed here. Thus, it would seem that mothers use communal musical resources to structure early triadic interactions. While this should be explored in future publications, these preliminary findings are auspicious.

Following this track could complement the multilevel analysis of the musical organisation we have started in this article. A detailed analysis of the coincidences between videos of the same child at different ages and between videos of different children at different ages would allow us to study how the intersegment, intrasequence (on-line), and intersequence levels of musical organisation are linked with other timescales of musical organisation. We refer, for example, to the ontogenetic timescale (the variation

of the musical organisation of interactions throughout the child's development) and the sociocultural timescale (the variation and sociocultural organisation of the interactive musical resources).

Considering the relationships between different timescales would allow us to account for the multilevel links that coexist in the musical organisation with more precision. For example, our results show that, at the intersegment and intrasequence levels, some rhythmic patterns repeat (S2). At the intersequence level, these patterns are enriched and elaborated (S2-S5). Videos belonging to our longitudinal study (Moreno-Núñez et al., 2017) show that these same patterns are used in other interactions of the same child with their mother and the maraca (ontogenetic level), and in triadic interactions in which other children from a similar cultural group take part, at different ages (sociocultural level). This suggests that different timescales form connections with each other, and that these connections are not random, but structured. Relationships would seem to organise following an enacted *holographic structure* (Raczaszek-Leonardi, 2018). In this structure, each piece carries information about processes that take place at different timescales. We propose that communicative musicality in early triadic interactions follows this structuring, and that the musical organisation on a given timescale establishes co-determination links with musical organisations in other timescales.

The different timescales of musical organisation make up a coherent system that adults use to interact with children from the first moments of life. And they usually do it with objects. As we have said elsewhere (Moreno-Núñez et al., 2015, 2017), pure diadicity does not exist, because human action occurs in material contexts with objects that can be instruments to interact and communicate with other people. And even when adults have more responsibility than children in linking with the material world, objects are always

protagonists of cognitive development. Our analysis shows the interweaving that exists between communicative musicality and the use of the maraca. Without the use of the maraca (RSDs), it would not have been possible for the mother to deploy the structures of musical organisation we described. And this means that without the use of the maraca the mother could not have interacted in the same way with her son. We suggest that, to understand early communicative musicality in all its complexity, object uses add valuable information. This study adds evidence to the research programme in early social cognition, incorporating new information about its music related aspects. However, these findings should be considered in the light of an important limitation: while quali-quantitative analysis typically draw on large samples in order to reveal significant insights, this is a single-case study. Future studies aiming to gain a deeper insight into these processes should therefore ensure the participation of more subjects. Therefore, further studies would be needed to recognise the status of the material world for psychological development, to take into account the referent of action in the context of early interactions, and to discuss the complexity of musical organisations using qualitative-quantitative analytical approaches.

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