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The Effects of Robot-Child Interactions on Interpersonal and Intrapersonal Coordination

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Abstract

Coordination is crucial throughout development, from motor development and language acquisition to children's play and other social interactions. Based on the links between motor and social behavior, proper coordination should help children connect socially with others. Being part of a larger study investigating the effects of a multisystem intervention tool for children with ASD, this work examined the effect of robot-child interaction on interpersonal and intrapersonal coordination in typically developing children. 5-year-olds and 7 year-olds participated in a four-week training protocol, where children had to copy the movements of a small humanoid robot. Measures of cross recurrence quantification analysis revealed that older children seem to benefit from the interactions showing improved interpersonal, but not intrapersonal coordination in simple clapping and maraca-shaking tasks.

The effects of robot-child interactions on interpersonal and intrapersonal coordination

Coordination is crucial in all aspects of development. The movement of individual cells to create functional organs, the synchronizing of muscles to perform simple movements, joining a conversation or being part of a group all require the coordination of action. Coordinated actions are so ubiquitous in everyday life that we tend to take for granted the synchronization of our own movements, as well as our synchronization with others.

Many findings representing a wide range of topics in developmental psychology emphasize the importance of coordination. Motor development, for example, can be characterized in part as increasingly sophisticated coordination with one's own actions and with the environment. The simple act of walking requires the coordination of many muscles. Major changes in coordination are typical over the first eight months of independent walking, when the range of motions decreases, and walking becomes more stable and economical (Marques-Bruna & Grimshaw, 2000). From maintaining our posture (Balen, Dijkstra, & Hadders-Algra, 2012; Riach & Hayes, 1987), through the first steps (Adolph & Berger, 2006), to hand-eye coordination (Wilmut, Wann & Brown, 2006), motor development requires coordinated action from our muscles/limbs.

Coordination early in development is also in evidence between individuals. For example, joint attention (Scaife & Bruner, 1967), the coordination of one's gaze with that of another, allows children to track the attentional states of other people. This simple phenomenon contributes to language acquisition, particularly learning new words (Tomasello, 1995). A number of studies have shown that toddlers' responsiveness to bids for joint attention predicted later receptive language development (see Mundy & Newell, 2007, for a review), even when controlling for general cognitive ability. Moreover, joint attention allows us to learn from others

about the world in general, as well as to learn about others, to understand what they might think or feel (Charman, et al., 2000).

Research on mother-infant interactions has focused on interpersonal coordination in a number of other ways as well. Studies show that during face-to-face interactions the heart rate of mothers follow the changes of their infant's heart rate and vice versa. This coordination of heart rates is stronger when there is a stronger coordination in their interactions (Feldman, Magori-Cohen, Singer & Louzoun, 2011). Another study showed that early in life, coordination of mother-infant emotional states has an effect on later self-regulation. Infants who were part of a dyad with more synchrony in their affective states during a play session at 3 and 9 months showed more self-control at 2 years of age (Feldman, Greenbaum & Yirmiya, 1999).

As additional examples of synchronized interpersonal behavior, the first social conversations between children and parents are also coordinated interactions that are cyclic and synchronous in nature (Fogel, 1993). This turn-taking behavior, although it does not contain words yet, is the base for communication patterns and further social interactions. Despite the early evidence for strong interpersonal coordination, there is also substantial developmental change in social coordination. For instance, children's interpersonal play is an important social interaction in development. Before children start to play with others, there is a stage of parallel play, when they only play next to each other, but there is little cooperation or interaction between them (Eckerman & Whitehead, 1999.). Eventually, children coordinate their behaviors into joint play, which allows them to explore social roles and interactions in an imaginative setting.

These examples from developmental psychology show how coordination is present in our everyday life and pervades a variety of developmental domains. The importance of coordination in these various domains suggests that these seemingly different areas (e.g., motor skills and

language acquisition) could be addressed by common underlying principles. This possibility draws support from well-established research on the coordination in a variety of other biological systems, as well as non-organic physical systems (Kelso, 1995). In nonhuman animals, a well-known example is the synchronized flashing of fireflies (Buck, 1988). This inter-individual behavior arises in large groups of fireflies. Although each firefly initially flashes in its own individual rhythm, they gradually become coordinated. The coordination of many thousands of insects without any central controller can be explained by considered them as biological oscillators that interact (Mirollo & Strogatz, 1990). In essence, the synchronization is achieved through a form self-organization.

Fireflies are not the only animals to show synchrony or coordination. Living in a group often means some kind of coordination between the individuals is necessary. For example, behavioral synchrony was also detected in baboons, where the strength of synchrony (doing the same or similar actions simultaneously during the day) was influenced by social and environmental factors, such as reproductive state of the females and differences between wooden or desert habitat (King and Cowlishaw, 2009). Similarly, synchrony was observed in pair-living animals too: red-tailed sportive lemurs synchronize their behavior if they are close to each other (e.g., they are in visible distance) (Fichtel, Zucchini & Hilgartner, 2011).

A number of qualitative, as well as quantitative, predictions follow from the hypothesis that coordination is a type of self-organizing phenomena. One simple prediction is that coordination should happen spontaneously, given sufficient interaction between the two systems. Richardson, Marsh and Schmidt (2005) tested this hypothesis using a well-understood paradigm, pendulum swinging and pairs of participants. In a series of two experiments, they had participants attempt to solve a puzzle together while swinging a pendulum (they were not

instructed to synchronize with each other). In one interaction condition participants could see each other, in another they could only interact verbally. In a control condition, they did not interact at all. Richardson et al. collected time series from the wrist movements. They found that in the visual-interaction condition participants spontaneously synchronized with each other. However, in the verbal-interaction there was little evidence for synchronization. The findings suggest that when two people are interacting and can see each other, synchrony spontaneously emerges, consistent with self-organization. Other quantitative predictions have been tested in this paradigm as well.

Even if one accepts the hypothesis that biological oscillators can spontaneously synchronize via self-organization, it seems clear that there is a developmental time scale along which the system is changing that requires additional explanation. That is, any biological system must undergo developmental change in order to become a biological oscillator capable of responding to a particular form of interaction (i.e., gaze direction). For example, a firefly pupa must mature into an adult before its structures can support synchronized flashing. Likewise, responsiveness to human interactions of various types must undergo development. Investigating the developmental processes that tune a child's responsiveness to social interaction has been challenging (Goldstein & Schwabe, 2008). We propose that targeting their synchronization skills may enhance these processes, specifically, that children's ability to coordinate with others can be improved. Although this improvement over time usually is the result of social learning, we propose that it will still occur when using a robot for "practicing". Here we take advantage of the human-like nature of robots to provide preliminary evidence that robot-child interactions can serve to tune children's responsiveness to adult-child social coordination.

Autism Spectrum Disorder

This work was part of a larger study with a goal to develop a multisystem intervention for children with Autistic Spectrum Disorder (ASD). ASD is characterized by a triad of behavioral deficits: social interaction, language/communication, and restricted and repetitive behaviors (DSM-IV). However, motor impairments in children with ASD are also present (Green et al., 2009; Ming, Brimacombe & Wagner, 2007) and could play an important role in their social development. Isenhower, Marsh, Silva, Richardson and Schmidt (2009) found that children with ASD perform less synchronous movements than typically developing children in interpersonal synchrony tasks, and their intrapersonal coordination also differs from typically developing (TD) children. In a bimanual drumming task, they were less able to maintain the required phase difference of the hands and their movements showed more variability than those of the TD children (Isenhower et al., 2012).

There are theoretical links between these motor impairments and the social behavior of children with ASD. One hypothesis is that proper coordination and perception would allow children to connect socially (Grensbacher, 2008; Leary and Hill, 1996). Early motor skills are predictors of later cognitive development, and social development too (Dziuk, Larson, Apostu, Denckla & Mostofsky, 2007). Being physically able to follow or respond to others' plays an important role in being socially able to understand them, their feelings, thoughts, desires, etc. (Isenhower et al., 2012).

The overall goal of the larger study is to investigate the effects of robot-child interactions on social and motor coordination of children with ASD. Ultimately, the intervention developed for children with ASD would function as a tool that can be used in a school setting or even by parents in the convenience of their home. Robots, because they are attractive and interesting to

children, seem like a good tool for intervention. Robots are simple, predictable, but still provide opportunities for interaction (they can "talk"), without the complex interactions that come with a human social agent.

Present Work

The current preliminary study focuses on the effect of robot-child interaction on interpersonal coordination in typically developing children. Interpersonal coordination is understood as the ability to synchronize our actions with others in time and space. The timing of the children's behavior depends on the timing of somebody else's behavior. The interaction between the children and the robot was established by a robot-imitation game, in which children were asked to copy the movements of a small humanoid robot. Through multiple sessions, the game provided opportunity for showing various actions by the robot and allowed for repeated meetings with the children. Before and after the robot-imitation sessions, we assessed children's interpersonal and intrapersonal coordination. Intrapersonal coordination is understood as the ability to synchronize the parts of our body to perform certain actions. In a series of simple tasks, like clapping with cymbals or shaking maracas, children first performed the actions on their own, then performed the same actions together with an adult, trying to match the adult's movements.

Comparing children's interpersonal coordination to their intrapersonal coordination is based on the specific nature of the training (robot imitation game). In the training sessions, children need to match somebody else's movements beyond coordinating their own movements. The skills required to follow the adult (and the robot) are more complex than the ones needed for intrapersonal coordination. Therefore, we predicted that the robot training would improve children's interpersonal coordination, because the robot-imitation game required following the movements of the robot, but should not have an effect on intrapersonal coordination.

Investigating the possible effects of the training protocol on TD children is important when planning to work with special populations. Our results will help to better understand how healthy children are affected by the intervention.

Method

Participants

Fourteen typically developing children participated in the study. They formed two age groups, the 5-years olds and the 7-years olds. All children were recruited through the University mailing list. The parents received all the information about participating in the study in person and signed the consent form during the first visit to the lab. Participants received 50 dollars at completion.

Materials

A commercially available, 6.5" humanoid robot (iSobot, TOMY Company, Ltd., see Fig.1.) was used for the imitation game. The robot was able to "talk" to the children: to greet them, say goodbye and similar simple utterances. A laptop was used to select each motion performed by the robot.

During the pre- and post-test, children were given small cymbals to clap with and maracas to shake. Motion data was recorded with a Polhemus motion tracking system at 240 Hz, with 2 markers on the hands, 2 on the feet (both experimenter and child).

Procedure

The study consisted of three phases: pretest, training, and posttest. The pre- and post-test sessions involved intra-personal coordination (i.e., coordinating their own movements) and inter-personal coordination (coordinating their movements with those of the human experimenter.)

The training sessions involved working with the robot. We describe the training session first, then the testing procedure used in the pre- and post test.

Training. We developed a four-week intervention protocol, the 'robot-imitation game', which consisted of eight sessions. A single session lasted for about 30 minutes and was divided into the following three parts: 1. *Warm up*: the robot greeted the child and performed a 'cool' action, like playing the drums while children were just watching. 2. *Robot-initiated imitation*: children were asked to copy the robot's various karate and dance movements (alternating them session to session). The movements were programmed to systematically increase in complexity over the sessions. After the robot performed a movement, we gave some time for the child to copy the robot, and prompted him or her if it was needed. There were 4-5 movements in each session, and all movements were repeated four times. 3. *Child-initiated imitation*: after the robot imitation period, the children were told that if they performed the actions from that session (e.g. dance) the robot would copy them (actually controlled by the experimenter through a laptop). The protocol was the same as in the robot-initiated part.

Testing. Before and after the training, we tested the children's coordination abilities. We recorded motion data for 20 seconds (which yielded times series of 4800 data points). First they were asked to perform simple actions like clapping with cymbals, shaking maracas and marching on their own (intrapersonal condition). Then children were asked to play a copying game with an adult leader (interpersonal condition), performing the same actions as before, thus giving us the opportunity to compare intra- and interpersonal data on the same task.

Analyses

Cross Recurrence Quantification Analysis. To quantify the coordination between two time series, we used cross recurrence quantification analysis (CRQA) (Webber and Zbilut,

1994). Recurrences are fundamental to dynamical systems, and can be used to describe their behavior (Marwan, Romano, Thiel & Kurths, 2007). If we want to examine the behavior of two systems, CRQA is a powerful method as require minimal assumptions about the nature of the data and provides an objective way to characterize synchrony between the two systems (Shockley, 2005).

The analysis is based on the graphical technique, called the Cross Recurrence Plot (CRP). A CRP is created by placing two time series on orthogonal axes. For every point in the plot we can calculate the distance between the two time series, creating a distance matrix. Next, it has to be determined what qualifies as recurrence: usually we set up a threshold, and if the two time series are within that distance, that point is counted as a 'recurrence'. If the two systems are within that distance for more than a single time step, a line forms, and the length of the lines measures the time while the two systems are 'recurrent', in the metric of time steps. The time steps are defined by the rate of measurement (here 240 Hz).

Although CRP is a great tool to investigate interrelations between time series, it is also possible to go beyond the visual impression of the behavior of the system. CRP has a limited dimensionality, which is not enough to describe the behavior of a complex system. Complex systems have many interdependent levels or dimensions that are continuously interacting (Gottlieb, 2007). To reveal the interactive nature of the system, we need more dimensions: instead of a two dimensional matrix, we have to reconstruct the phase space of the system (Figure 2.). The phase space is a multidimensional space that contains all the possible states of the system. Takens' theorem states that phase space can be reconstructed using only a single time series (Takens, 1981). To reconstruct the phase space, we use delayed copies of a single time series. Our first dimension is the original time series, starting at time point 1. Our second

dimension is a copy of the same time series, starting with a delay (x). Following this, the third dimension starts at 1+2x, the next at 1+3x, and so on (see Figure 3.). The number of dimensions is a fundamental question, as we want to reveal as much of the behavior of the system as possible, but using only dimensions that are necessary (and not more). We stop increasing the number of delayed copies of the time series, when the new reconstructed phase space will not describe our system better than before. Here we used an embedding dimension of 6, based on preliminary analyses as described by Abarbanel (1996). The other important question for reconstructing phase space is the amount of delay. Again, as we want the most information about our system, we should choose the delay to maximize the difference between the original and delayed time series (and minimize that mutual information they carry). Here we used a delay of 50 data points, again following recommendations from Abarbanel (1996).

In CRQA both time series are embedded in one phase space that allows us to determine when the two systems are in roughly the same location (Shockley, 2005). When their trajectories are within a given radius, it qualifies as a recurrence. The magnitude of the radius was set to allow a given percentage of recurrent points, 8%. Repeated recurrent points allow us to measure the length of time when the two systems are in the same region of phase space (Figure 4.). From these measurements, we obtain a set of variables that are informative about the joint behavior of the systems. The measures that are usually reported are the meanline, maxline, entropy and determinism (and recurrence rate if the radius is not determined by the ratio). The names come from the cross recurrence plot where if we connect the points that are recurrent, we get lines parallel to the diagonal that differ in length, depending on the number of consecutive recurrences. These measures are defined below.

Meanline: measures the average amount of time during which the two systems are very close together, within a given radius, in the phase space.

Maxline: gives us the longest time while the two system are within the distance of the radius.

Entropy: is a measure of variability of the line length distribution. It is the Shannon entropy of the distribution of line lengths.

Determinism: is the percentage of recurrent points that from lines (2 points were considered a line here).

To investigate the possibility of changes in these various recurrence metrics over time, we applied an *epoching* procedure. For each child, the length of recorded time series was 4800 data points (over 20 seconds) for each session. We broke this long time series up into epochs. Each epoch consisted of 1000 data points. Adjacent epochs overlapped by 200 points. This allows us to examine changes in child-adult coordination over time within a single session.

Results

The majority of children were able to successfully complete both the pre- and post-test. Data from one participant was lost because they were unwilling to wear the motion tracking markers. An additional participant's data was not included in the analysis because the time series were exceptionally disordered.

Clapping

We first report the results of the CRQA on the clapping data. The means of the CRQA variables for the two age groups are shown in Table 1, separately for pre- and post-test for the intra- and inter-personal conditions. As mentioned before, we used an epoching strategy to allow for possible changes within a trial. Thus, each trial in both the pre- and post-test contains five epochs; a separate CRQA was conducted for each epoch. We analyzed the measures produced by

CRQA using growth curve analysis (Singer & Willett, 2003). We ran GCA on the main variables (meanline, maxline, entropy, determinism) separately. We take *z* scores greater than 2 to be significant at the .05 level throughout.

Meanline. Figure 5, panel a shows the average meanline as a function of epoch with a separate curve for the intra- and interpersonal conditions. The upper panels show the 7-year-olds, pretest on the left, posttest on the right side. The lower panels show data from the 5-year-olds, pretest on the left, posttest on the right. Applying growth curve analysis on the meanline variable, 7-year-olds showed a significant improvement for interpersonal, but not intrapersonal, coordination (time x social = 10.42, z = 3.60). 5-year-olds did not show this effect coordination (time x social = 4.48, z = 1.35). The younger group also had harder time altogether in the interpersonal condition when they had to coordinate with another person (social = -13.96, z = -2.37). Additionally, we found an overall decrease over time (time = -4.97, z = -2.08).

Maxline. Given that these variables are strongly related to each other, it is not surprising that we found the same pattern in the results of the maxline variable (Figure 5, panel b). The improvement in the older age group was found only in the interpersonal coordination, but not in intrapersonal coordination (time x social = 124.52, z = 2.83), whereas the younger age group showed a decrease in time (time = -71.002, z = -2.14) and lower values for interpersonal condition (social = -166.70, z = -2.15).

Entropy. The interaction of time and social condition was found for entropy too (time x social = .86, z = 3.52), showing an increase in variability over time in the interpersonal coordination, but not in the intrapersonal coordination for the 7-year-olds (see Figure 5, panel c). For the 5-year-olds there was no significant interaction (time x social = 0.23, z = -0.76).

Determinism. The last panel of Figure 5 illustrates that the older age group showed increase in the determinism measure in the interpersonal, but not in the intrapersonal condition (time x social = 0.16, z = 3.07). This interaction effect was not found in the younger age group, but they showed significantly less determinism in the interpersonal condition than in the intrapersonal (social = -0.25, z = -2.14, see Figure 5, panel d).

Shaking Maracas

We ran the same analyses on the CRQA variables from the maraca-shaking task. The means of the CRQA variables over the epochs and across participants are shown in Table 2, separately for pre- and post-test for the intra- and inter-personal conditions.

Meanline. Growth curve analysis on the meanline variable (Figure 6, panel a) showed an interaction effect between time and social condition (time x social = 11.281, z = 2.443) in the group of 7-years-olds, but although there is a slight increase in interpersonal coordination, the interaction mostly comes from the decrease in the intrapersonal coordination over time. In the younger age group, we also found an interaction (time x social = 17.276, z = 2.745), with more increase in the interpersonal condition over time.

Maxline. Following the pattern of the previous measure, the interaction of time and social condition seen in the older age group is present for the maxline measure too (time x social = 143.004, *z* = 2.33), with a decrease in the intrapersonal coordination and small increase in interpersonal coordination. The 5-year-olds show a marginal, but not quite significant interaction (time x social = 157.556, *z* = 1.943). The only a significant overall difference between social conditions (social = -382.133, *z* = -2.478), and pre- and posttest (time = 113.755, z = -2.678). See Figure 6, panel b.

Entropy. We found significant interaction of time and social condition in the older age group for this measure too (Figure 6, panel c) where the children showed increase in the interpersonal, but not in the intrapersonal condition (time x social = 0.915, z = 3.504). The same effect was not found for the younger age group (time x social = -0.062, z = -0.214).

Determinism. The growth curve analysis showed a significant increase in interpersonal coordination, but not for the intrapersonal coordination over time (time x social = 0.249, z = 4.018) for the older age group (Figure 6, panel d). The younger age group did not show this interaction of time and social condition (time x social = -0.121, z = -1.913).

Discussion

We proposed that interpersonal coordination would improve from pre- to posttest, but there would be no change in the intrapersonal coordination. The results supported our expectations partially, yielding interesting patterns in both the clapping and maraca-shaking task.

When looking at clapping, we found that our expectations were met in the older age group. All measures showed increase in interpersonal, but not intrapersonal condition. For the younger age group we found overall decrease in meanline, maxline and nonsignificant increases in entropy and determinism.

The results of the maraca-shaking task differ from those of the clapping task. The meanline measure showed an interaction between time and social condition, but the increase was not significant in the interpersonal condition when looking at the older children. Rather, the decrease in intrapersonal condition was responsible for it. On the other hand, the younger group did show an increase in interpersonal condition, which was not present for the intrapersonal condition. This significant increase disappeared for the maxline variable in the 5-years-olds, although it is still marginally significant. For entropy, the same interaction is present for both age

groups, showing an increase in interpersonal but not intrapersonal condition. Determinism also has this interaction in the older age group, but it is not present in the younger age group.

Our results show a specific effect of the robot training: the interaction with the robot improved the interpersonal coordination of the older age group in the clapping task, but children in the younger age group showed no improvement. This could mean a developmental difference: clapping seems to be harder task; younger children had a really hard time with coordination when they have to adjust to others. Consistent with this idea, Fitzpatrick, Schmidt and Lockman (1996) also found that the clapping in the younger age groups is less coordinated (thus more variable), and it was easier to perturb young children's clapping by loading the wrist. This age group may not ready for this kind of training, their motor abilities are below what the task requires.

In the intrapersonal condition, when they are left to perform the actions on their own, in a self-selected pace (and manner), they are doing better than when they have to follow the adult. This difference is not seen in the older age group. Asking children to copy the movement of an adult is a harder task for 5-year-olds than for 7-year-olds. In addition, the constraint of the task may also be adding to this difference. Complex systems have preferred frequencies, at which their performance is at peak (Strogatz, 1994). However, we have chosen the frequency on purpose to be slower than what would be natural for a child, to challenge them. For the younger children, this seemed to be too challenging, and very difficult to follow. Choosing different frequencies for the two age groups might be useful in future work.

In contrary to the effect seen in clapping task, the robot-child interactions improved the interpersonal coordination of the younger children in the maraca-shaking task, but the older children showed no improvement. This certainly seems to undermine any argument about their

being a fundamental difference in the ability to coordinate between the two age groups. However, one could also argue, that the situation is not that simple, we have to take into account the nature of the task itself. Clapping and shaking maracas are similar task in terms of symmetry: we are using simultaneously the same muscles to coordinate the movements of the hands (in-phase movement). But clapping does appear like a more difficult task, because of the need to "meet" in the middle, especially with cymbals, while shaking maracas one does not have to worry about this.

Further, we have to consider the tools in the children's hands too. We used small, age-appropriate cymbals and maracas, but the two age groups could differ in what the optimal size of the tools would be for them. The size of the tools is tied to the problem of frequency that we choose to challenge the children, given that the "load" that it puts on the hand of the (especially younger) children, can affect the frequency the children feel comfortable clapping/shaking with.

Although comparing interpersonal to intrapersonal coordination has precedents, might not be as obvious to interpret the relationship of the two different actions (coordinating their own hands, vs. coordinating their clapping to somebody else's). We argued that there is a special situation in the robot training that should affect only the interpersonal coordination. Still, the lack of a real control group brings up the problem of spontaneous learning over time. Clearly, the biggest downside of the study in this preliminary state was the lack of real control groups.

The improvement in interpersonal coordination between the pre- and post-test might be the result of learning in itself. The "practice" of the task (there were many trials) at the pretest might have had a lasting effect and the better performance in the posttest is showing only that (e.g. even without the training children would be better on the same tasks). Still, there is something that makes us think that our choice of comparison makes sense. In the intrapersonal

coordination there is no improvement over time in the whole dataset. The interpersonal coordination effects do not appear to be due to getting better at coordinating one's own behavior (e.g., becoming a better "clapper").

Therefore, we interpret these findings tentatively as an effect of interacting with the robot. This suggests that the intervention may have a potential to increase children's ability to synchronize with others.

Figures

Fig.1. iSobot, the small humanoid robot

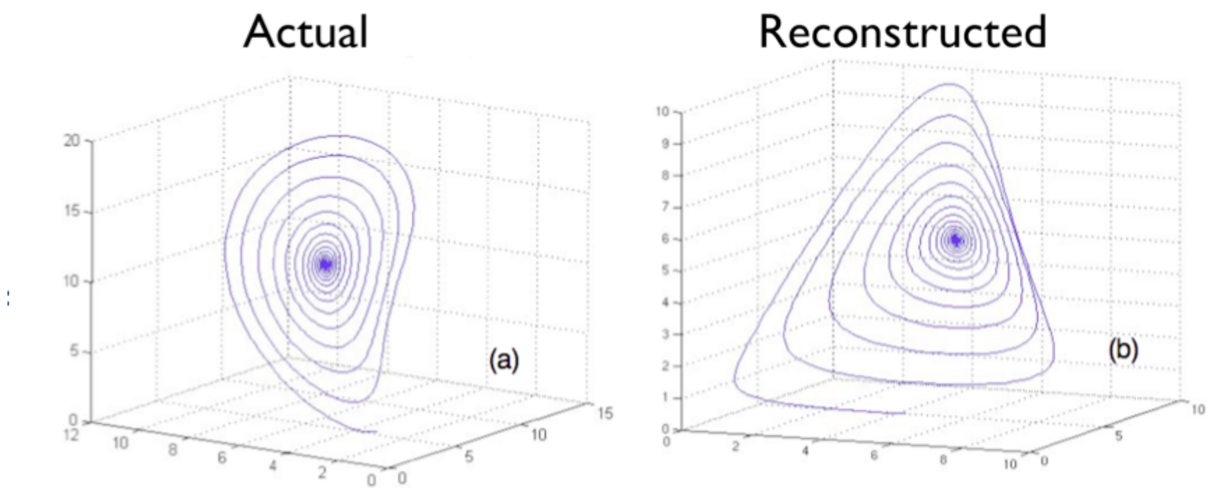

Fig. 2. Reconstructed phase space (b), compared to the actual plot of the system (a).

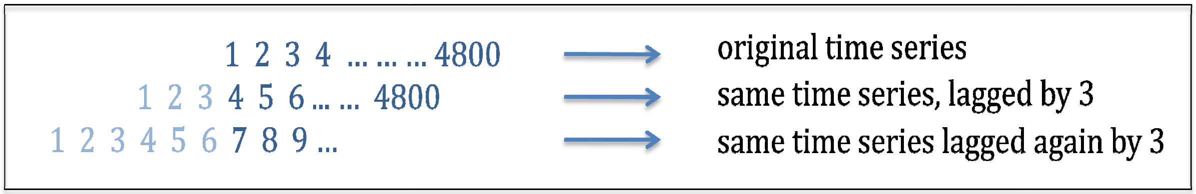

Figure 3. Phase space reconstruction by lagging copies of the same time series, with an embedding dimension of 3.

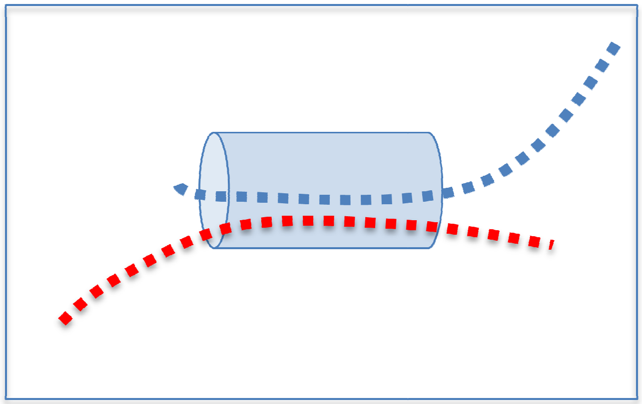

Figure 4. Repeated recurrences. We can measure the length in time when the two systems are within the set radius.

Table 1. Means of the CRQA variables – clapping with cymbals

a) in the younger age group

5-year-olds	Intrapersonal		Interpersonal	
	Pre	Post	Pre	Post
Recurrence Rate	0.047	0.045	0.015	0.014
Determinism	0.867	0.766	0.712	0.717
Meanline	20.631	15.597	11.485	11.045
Maxline	175.900	105.000	67.130	50.150
Entropy	3.140	2.797	2.417	2.374

b) in the older age group

7-year-olds	Intrapersonal		Interpersonal	
	Pre	Post	Pre	Post
Recurrence Rate	0.019	0.021	0.013	0.040
Determinism	0.825	0.788	0.752	0.880
Meanline	12.451	13.219	11.100	22.919
Maxline	65.080	93.330	51.110	213.000
Entropy	2.824	2.709	2.491	3.272

Table 2. Means of the CRQA variables – shaking maracas

a) in the younger age group

5-year-olds	Intrapersonal		Interpersonal	
	Pre	Post	Pre	Post
Recurrence Rate	0.048	0.023	0.012	0.023
Determinism	0.874	0.879	0.812	0.765
Mean line	33.891	19.004	11.072	16.360
Maxline	303.880	185.300	25.060	138.300
Entropy	3.364	3.135	2.386	2.596

b) in the older age group

7-year-olds	Intrapersonal		Interpersonal	
	Pre	Post	Pre	Post
Recurrence Rate	0.067	0.045	0.016	0.017
Determinism	0.941	0.930	0.682	0.869
Meanline	57.568	28.224	14.869	15.990
Maxline	445.700	300.800	107.130	116.400
Entropy	3.740	3.595	2.320	2.942

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