23

# The Mirror Game: A Natural Science Study of Togetherness

Lior Noy

## Prologue: A meeting point

I am interested in the liminal area between science and the arts. The separation of the two is evident in our culture[1]: science, objective and logical; art, subjective and intuitive. For me this separation was always a bit strange. I am a performer, an actor in Playback Theatre, an improvisation form based on real-life stories.[2] I am also a scientist, trained as a computational neuroscientist. In 2008, the last year of my PhD studies, I received an offer to bring together my two vocations. Prof Uri Alon, a renowned physicist and molecular biologist and a fellow Playback actor, invited me to explore with him the possibility to study performance from a scientific perspective.

This was the beginning of a journey that started, as it often does in research projects, with a long time of wandering in 'the cloud'[3] while searching for the right research question and methodology. We met one evening to try to break our impasse. Sitting at the bar of our favourite place in Tel-Aviv, we had a moment of grace. As Uri is trying to gauge what I am *really* interested in studying, I found myself talking about the mirror game, a basic theatre exercise in which two actors mirror each other, creating coherent motions together. I recalled an experience from a time I was teaching theatre at a youth ward in a psychiatric hospital. A young man, who did not participate in other activities in the ward, had come to my class and had joined the activity only when we played the mirror game, and only when his favourite guide could play with him. It seemed that the game offered this young man an opening which was not present elsewhere. Talking about this experience, we instantly realized that the mirror game could be a fascinating object for a scientific investigation. We felt that the game relates to the profound human experience of being in a state of *togetherness*, while being simple enough to be studied quantitatively. This insight led to the study I shall describe here, and later, to the establishment of a Theatre Lab at the Weizmann Institute of Science, a hub of research at the meeting point of science and performing arts.[4]

## Applying a natural science approach to the study of performance

Several current research fronts study elements of performance using a natural science approach. I am referring here to the natural sciences in order to focus on studies applying rigorous measurements, controlled experiments and mathematical modelling to study performance. These studies belong mainly to the field of neuroscience, which in the last two decades has expanded into new territories in the behavioural and social sciences, including studies of elusive phenomena such as meditation[5] and the human moral sense.[6] A recently emerging subfield is *social neuroscience*, aiming to apply the tools of neuroscience to study social interactions[7] such as joint action[8] and storytelling.[9]

Much of the recent progress in neuroscience is the result of advances in brain imaging techniques, most notably the introduction of functional magnetic resonance imaging (fMRI). For studying performance, an fMRI experiment poses a serious challenge: participants are expected to lie still for an hour or so, situated within a claustrophobic metal tube. This experience is quite different from that of, say, a performing Jazz musician. Due to this challenge, most studies in the field focus on studying the experience of *perceivers* of a performance, most notably during the perception of music, with only a handful of studies applying brain imaging to study the production of performative acts in music[10] and in dance.[11]

Studying a full performance, Ivana Konvalinka has recently measured physiological arousal in a fire-walking ritual in rural Spain.[12] Measuring the heart rates of spectators and performers, she found a pattern of physiological synchronization: while the heart rate of the current fire-walker was in-sync with that of related spectators (close friends and family members), it was out-of-sync with that of unrelated spectators. This work echoes previous studies of the physiological basis of trance states in rituals[13] and suggests a link between behavioural and physiological synchronization, a hypothesis currently being explored in our lab.

A few recent studies examined the brain activity of *improvising* performers.[14] Charles J. Limb and Allen R. Braun found that during improvisation, Jazz musicians exhibit different patterns of brain activation, including a deactivation of extensive parts of the pre-frontal cortex, an area containing the *executive functions* of the brain, and regulating other brain areas. The inhibition of pre-frontal activity during improvisation might be related to the concept of an *inner critic*, defined by improvisation pioneer Keith Johnstone as the part of our mind that constantly monitors and censors our actions. Johnstone suggested that in order to promote the emergence of spontaneous improvisation, the inner critic needs to be inhibited, and suggested practical methods of achieving this such as trance masks work.[15] A speculative hypothesis can relate the deactivation in the pre-frontal cortex of improvising Jazz musicians with Johnstone's inner critic.

Son Preminger suggested that theatre improvisation could be used as a method for neurocognitive rehabilitation. She describes similarities between known theatre improvisation exercises and methods used to assess damage to pre-frontal brain area, claiming that both engage similar cognitive functions. In her work, improvisation exercises are integrated into a practical framework for neurocognitive rehabilitation, an example for the potential of new discoveries at the intersection of neuroscience and the performing arts.[16]

Whereas the aforementioned studies focus mainly on studying brain activation of viewers and performers, we have taken a different approach, rooted in physics. We wished to reduce a complex behaviour pattern during performance to a *model system*. A model system is a relatively simple system that can be studied rigorously, attaining insights that can be projected onto more complex systems. An example of a model system commonly studied in molecular biology is the *E. coli* bacterium, an organism with a relatively short genome that contain many of the genetic regulations mechanisms that appear also in the human genome. A good model system enables researchers to conduct controlled experiments, and to extract simple measurements that can be analysed mathematically, while keeping contact with the phenomenon of interest. We suggest that the mirror game exercise can be employed as a model system for studying togetherness in performance.

## Togetherness and the mirror game

A group of people acting together can enter a unique state of spontaneous and highly synchronized action. Director Peter Brook describes such moments during rehearsals, in which group creativity is at its peak: 'For these moments, when feelings, words, and movements came together and fused into new life, depended on the "running of a current," an opening to which all present contribute.'[17] Avant-garde musician Holger Czukay recalls similar moments: 'I have good memories about nights or concerts where we didn't play the music rather . . . the music played us.'[18]

I refer to moments in which the 'music played us' as moments of togetherness. A related term is Victor Turner's *communitas*, the experience of a group going through a ritual transition, where gender and class boundaries are dissolved, and group members experience unmediated direct connections.[19] Amy E. Sheams, in her book on Chicago's 'Second City' improvisers, describes *being in the zone*: '. . . a state of unselfconscious awareness in which every individual action seems to be the right one and the group works with apparently perfect synchronicity.'[20] *Being in the zone* is also a familiar term in group sports.[21]

To study these moments, we used the mirror game, a common exercise from theatre and dance practice.[22] In the basic form of the exercise, two players stand in front of each other, making eye contact. The players are instructed to produce synchronized mirror-like motions. The game starts with periods in which the players explicitly alternate between leading and following. Following an external cue, the players enter a period of co-creation, producing the synchronized motion together without a designated leader. Usually the mirror game is used as a tool to achieve concentration, attention, listening, and is typically employed as a warm-up exercise. Richard Schechner emphasizes the centrality of mirroring in performance: 'The theatrical event is fundamentally a mirroring; an ensemble company is a group of mirrors reflecting each other.'[23] In his work, he extensively used different mirror games to promote togetherness. Describing a mirror game involving four actors, he writes: 'Ego boundaries between individuals are breaking down. The progression . . . is one of breakdown and reformation on the basis of mirroring until from four individuals one entity emerges.'[24]

We employed the mirror game in an experimental setting to study togetherness. The requirement to produce identical motions establishes a natural way to quantify the dyad's performance by recording the motions of the two player motions and measuring their similarity. Our working hypothesis was that it is possible to detect markers of the subjective feeling of togetherness in the dyadic motions in the game. Our aim was to define these markers and to suggest a possible mechanism for the emergence of togetherness.

## The experimental setting

Measuring the motions in the mirror game exercise entails a non-trivial task: the recording and analysing of the entire body motion of two actors. To overcome this, we simplified the experimental system and studied a reduced version of the mirror game in which only linear motion of the hands are allowed. For this purpose we developed a custom device for measuring the linear motion of two players (Figure 22, top-left). The players face each other, holding handles that can move along parallel tracks half a metre long, and the motion of the handles is accurately recorded. The one-dimensional mirror game enables players to produce rhythmic motions at different amplitudes and frequencies. Interesting motion patterns can be discovered; for example, a continuous increase in motion frequency leading to a clear crescendo (Figure 22, top-right). With this device,

AQ: Please note that Figure 1 has been changed to Figure 22.

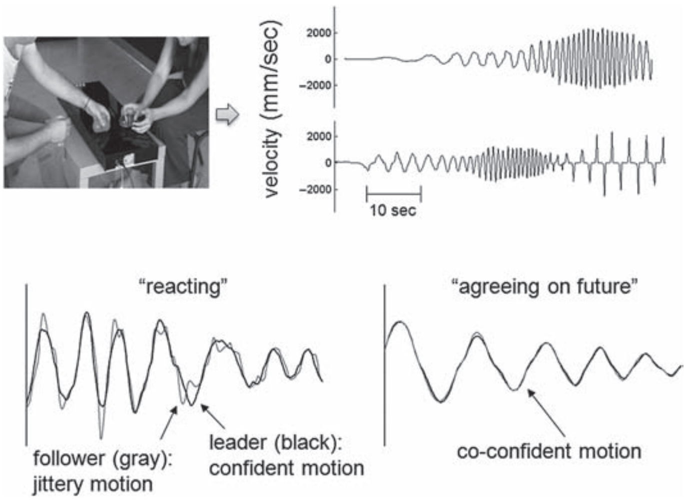


**Figure 22 Top: the one-dimensional mirror game set-up.** Two actors move handles along a line, mirroring one another with or without a designated leader. A custom-made device accurately measures the motion of the two handles. Two velocity traces, taken from rounds without a designated leader, show synchronized motions with complex patterns, for example, crescendos and diminuendos. The motion trace of one of the players was omitted here for clarity. **Bottom: a kinematic marker of togetherness.** A typical motion traces when one player is leading (black line) and the second player is reacting (grey line) are shown on the left. Notice the additional jittery motion on top of the leader's confident motion. In contrast, in joint-improvisation rounds, players can enter periods where they both produce synchronized and co-confident motion, without the typical jitter of followership. We suggest that in these periods the players do not react to each other, but instead agreeing on the current 'game', entering a momentary state of togetherness.

players were asked to play together and the goal of the game was defined as 'enjoy creating motion together that is synchronised and interesting'.

Moments of togetherness are rare in life, and it is difficult to capture them in the lab. To enhance our chances of detecting such moments, we focused on expert improvisers, operationally defined as actors or musicians with over 10 years of experience in joint improvisation. A similar approach was used in brain studies of meditation, where researchers investigated extremely experienced Tibetan monks in order to study meditation under laboratory conditions.[25] As a control group we also tested people without prior experience in improvisational arts.

We analysed the behaviour of pairs of expert improvisers in the simplified mirror game.[26] Players played a game composed of nine one-minute rounds, alternating between leader-follower rounds (with a designated leader) and joint-improvisation rounds (without a designated leader). Rounds were separated by ten-second breaks in which the players were allowed to remove their arms from the handles. The short rounds and the breaks were designed to assist players not to stay in a posture that might be uncomfortable for a long time. This was a limitation of the developed set-up, and we note that the duration of the rounds is shorter than what is commonly found in the mirror game exercise.

A game started with a short practice to allow players to get used to the possible motions. The progress of game rounds was conveyed to the players via a set of lights on the device, and a bell sound. Players were asked not to speak during the game. To allow for an intimate space, the experimenter left the room during the game.

## The experimental results

Our findings show that expert improvisers create complex and highly synchronized motion together (Figure 22, top-right). To evaluate synchronicity in the motion, we segmented the velocity traces of the handles' motion into segments between stopping and found that the difference in segments stopping-times between the two players was often smaller than the minimal human reaction time (around 100 milliseconds). This suggests that players do not only react to the motion of each other but also use a prediction mechanism to anticipate the future motion.

Comparing the stopping time-differences in leader-follower and joint-improvisation rounds, we found that on the average, expert players were more synchronized in joint-improvisation rounds.[27] Moreover, when comparing both the speed of the motions and the produced errors, we found that in joint-improvisation rounds players were able to reach a region of performance that was not reached in leader-follower rounds.

We also analysed the behaviour of novices, people without improvisation experience, and showed that novices display the opposite pattern: they are less synchronized in joint-improvisation rounds, and show a smaller range of motions, showing that the joint-improvisation task is inherently challenging.

We then applied a detailed analysis of the motion traces to understand the source of the enhanced performance in the joint-improvisation rounds. We found in the motion traces of the follower a characteristically high-frequency motion that oscillates around the leader's confident motion, and we termed it *jitter* (Figure 22, bottom-left). This motion is typical of a scenario in which one agent (e.g. a hunting dog) chases another one (e.g. a rabbit). The dog is only reacting to the motions of the rabbit, without an ability to predict its future motions. As the rabbit changes its course, the dog zigzags across the rabbit's path, over- and under-shooting due to the inherent delay in reacting.

Previous studies of eye and arm movements describe similar jitter motion when tracking a target whose motion is not predictable.[28] This jitter motion was considered to be the result of an inner corrector, a reactive component in the brain that tries to correct the current error between the motion of the eye and the motion of the target. Similarly, we suggest that the jitter motion pattern found in the motion traces of the follower in the game is the result of an inner corrector, reacting to the perceived error between the motion of the leader and the follower. The detected jitter can thus be used as a *marker of followership* in the mirror game, characterizing periods when one player reacts to the motion of the other.

This aforementioned analysis allows us to show that during joint-improvisation rounds, expert improvisers not only switch (implicitly) between leader and follower roles, but also enter periods in which they create the motion together. We find that in about 15 per cent of the time in joint-improvisation rounds, expert improvisers produce smooth and synchronized motion, with neither of them displaying the characteristic jittery motion of a follower (Figure 22, bottom-right). Borrowing a term from drawing, we defined the smooth and synchronized motion of the two players as *co-confident* motion. These periods lasted usually for 5 to 20 seconds. The co-confident motion periods usually contained some development of the motion, for example, an increasing frequency up to some breakup point. We suggest co-confident motion periods as an operational description of moments of togetherness in the mirror game. As a control, we note that pairs without improvisation experience almost never exhibit this pattern of joint motion.

Finally, we developed a mathematical model for the behaviour of the players in the game. The motion of each player is the sum of two controllers: a *reactive* controller, which attempts to match the produced motion to the perceived motion of the other, and a *predictive* controller, which attempts to learn the motion of the other player and to predict it in advance. In simulations, this model produces motions that resemble the experimental results, including the emergence of co-confident motion when two such models are linked in mirror configuration. The model suggests that high synchronization in the mirror game is the result of a temporary cancellation of the reactive behaviour.

To summarize our results: we have shown an experimental paradigm to study joint-improvisation, presented an operational definition of moments of togetherness and suggested a mechanism for the emergence of these moments, based on reactive-predictive controllers. We are currently conducting several follow-up studies extending these results. We are particularly intrigued by a possible connection between the jitter in the mirror game, the mathematical reactive controller discussed above and the improvisation concept of an 'inner critic', and are exploring ways to bridge these concepts.

## Regarding the reductionist nature of our approach

There is an inherent reduction in a scientific study of performance, where one attempts to reduce a nebulous concept to a well-defined experimental system. In this study the phenomenon of togetherness is reduced to a set of measurements of liner motions, a substantial move, from the transcendent to the very grounded. We aim to *distil* the phenomenon of togetherness, but in reducing it so much, do we manage to keep in touch with the original phenomenon?

I encourage the reader to come up with her or his own judgement for this question. Personally, I believe the answer is yes, that the moments of high synchrony in the mirror game reflect the subjective state of togetherness. In any case, there is a need for modesty: we did not *explain* the mystery of togetherness. We took, hopefully, a small step towards studying togetherness in a rigorous manner. We are currently taking further steps in this direction by performing further studies on the simplified mirror game, and by developing new paradigms to study more complex systems of joint-improvisation, such as the regular mirror game and joint drumming.

Another possible concern regarding our approach is that it will be so successful as to 'explain away' the phenomenon, reducing the magic of being in the zone to a set of mechanistic equations. I regard this concern in two manners: first, I do not think this scenario is very likely. As a performing improviser, I have a direct (subjective) access to the intensity and the complexity of joint-improvisation. I believe that the type of intuitive group decisions that we constantly make on stage is extremely difficult to analyse and model. But even if I am wrong, and one day someone will fully model a group going into the zone, this will not explain away the *experience* of these moments. The subjective experience in the moments when the 'music is playing us' is so vivid, and so unique, that any objective explanation will not replace it. An objective description can only co-exist alongside our subjective reality. Personally, I am slowly coming to grip with the notion of *multiple realities*, suggesting that we can simultaneously comprehend an objective description of a human experience *and* be fully in touch with its subjective reality. In the end, accepting the simultaneous existence of objective and subjective realities might be the final manifestation of togetherness.

## Epilogue: A performance

Ruth Kanner is a renowned Israeli experimental theatre director, famous for her staging of non-dramatic texts. We recently started a dialogue that led her to suggest the following experiment: what would happen if we employ her group's skill to transform a *scientific* text to the stage? We decided to perform Kanner's experiment, and to have her actors improvise on the scientific paper describing the work presented here, to improvise on a text on joint-improvisation.[29] We planned a three-part performance: a flash presentation of the mirror game science project, a piece from a previous production of Kanner's group, which was influenced by scientific ideas about chaos and randomness, and then, a live experiment: four actors improvising on the text of the scientific mirror game paper, working their way from the most technical lines ('$p < 0.05$' – try to sing it!) towards the more comprehensible conclusions.

Something very intense was created as the performers explored their way through the text. At least for me, the performance had a transformative quality. Hearing the actors' voices, I felt that they manage to extract from the text the frustration and the joy of 3 years of hard work. They manage to unpack emotions that were condensed into the technical 2,500 words of the published paper. It was Playback Theatre at its best: my story coming to life on stage, illuminating words with hidden meaning. We wrote 'Togetherness' with an implicit agenda: 'it is so nice to be together!'. There is also a dark side to togetherness, which the actors managed to feel and to convey. Towards the end of the piece, the four actors started a wonderful joint singing of our key concept: 'To – ge – ther--rrr-ne—ssss'. In the midst of this collective work, one of them rebelled. Diverging away, she flew into her solo adventure, telling us that she prefers not to march in order, not to adhere to our definition of 'togetherness'. She prefers to play now, if we do not mind, and can we, please, not take ourselves so seriously.