Movement similarities and differences during social interaction:

The scientific foundation of the ALTEREGO European project

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Abstract—Schizophrenia, autism, or social phobia are typically accompanied by social interaction deficits. The objective of the AlterEgo European project is the creation of an interactive cognitive architecture, implementable in various artificial agents, allowing a continuous interaction with patients suffering from social disorders by virtue of changes in behavioral (robot-based) as well as morphological (avatar-based) properties of that agent. Here we present the scientific foundations of the project and its four main experimental steps. The results of the first similarity experiments are reported, which show that healthy participants functionally adapt their social motor interaction when they interact with agents (real or artificial) morphologically and behaviorally similar to, or different from, them. These results obtained with healthy participants have consequences for the rehabilitation of socially deficient patients.

Keywords—Similarity; Difference; Social interaction; Morphology; Kinematics

I. INTRODUCTION

Social pathologies, including schizophrenia, autism and social phobia, are mainly characterized by difficulties in interaction with others. This causes much suffering both for the patients and for those around them. The AlterEgo European project (2013-2016) aims to develop and test an innovative rehabilitation method to improve such relational deficits, using humanoid robotics and virtual reality. The project is rooted on a trans-disciplinary theory coming from movement neuroscience and cognitive science: the theory of similarity. This theory suggests that it is easier to socially interact with someone who looks like us. This resemblance can be morphological (form of a person), behavioral (his/her actions), or kinematic (the way s/he moves). In the AlterEgo project, an avatar (virtual agent) and a humanoid robot (the European iCub robot) are used to manipulate these three components of similarity in real time situations of social interaction between patients or healthy participants and the artificial agent. In this contribution, we introduce the theory of similarity and its predictions, before briefly presenting the first results obtained in human-to-human and human-to-avatar interaction situations.

II. SIMILARITY IN SOCIAL INTERACTION

In humans, similarity is a crucial determinant for social interactions and interpersonal attraction. Several studies in social sciences have demonstrated that people are strongly attracted to physical and behavioral look-a-likes appearances (see [1] for a meta-review). The more people match, the happier people are in a relationship [2]-[3]-[4]. Research has also shown that people move rhythmically in interaction and tend to synchronize their movements [5]. Likewise in motor control, multiple studies have shown that when two people possess similar movement frequencies, they spontaneously coordinate their movements with each other [6]. Other research in the field has demonstrated the chameleon effect, namely that people tend to unconsciously match postures, mannerisms, and facial expressions of people they interact with [7]. This behavioral similarity increases interpersonal rapport and pro-social behaviors [8] in three main components: physical resemblance, temporal correspondence and behavioral matching.

A. Physical resemblance

Myriad of studies in human-human interaction, human-avatar interaction, and human-robot interaction have demonstrated that people are strongly attracted to physical look-a-likes appearances. In human-to-human situations, the similarity-attraction theory suggests that similarity serves as a reinforcer [9]. Leader-follower similarities and dyadic interactions with similar people reinforce each member of the dyad, generate positive feelings and attraction. In opposition, interaction with a physically dissimilar person can sometimes be associated with anxiety, confusion, potentially leading to a lack of attraction or even a feeling of repulsion.

In human-robot interaction, the question of physical anthropomorphism — of how much robots should resemble humans, see Fig. 1 — is still heavily debated. Anthropomorphism and human expressiveness can induce natural human reactions and simplify communication [10]-[11]. However, due to the powerful influence of the Uncanny valley hypothesis (e.g., [12]-[13]), the issue of similarity has not been rigorously tested in the human-robot interaction community.

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The Uncanny valley hypothesis was recently revisited (see Fig 2). Reference [14] suggested that the existence of the Uncanny valley could be caused by the poor quality of aesthetic designs, a suggestion that was recently confirmed by behavioral and neurophysiological studies [15]-[16].

B. Behavioral matching

Research in social psychology has shown that interpersonal coordination can facilitate reciprocal imitation [17], making the interacting individuals more likable [18]. Similarly, when two people are engaged in an activity requiring motor coordination, such as walking, dancing, or singing, cooperation and social attachment are enhanced [19]. The chameleon effect — our unconscious tendency to match postures, mannerisms, and facial expressions during social interaction — is another form of behavioral matching which increases interpersonal rapport and pro-social behaviors [20]. A link between the perceptual-motor processes engaged in interpersonal coordination and mental connectedness thus seems to exist during social interactions, which however lacks experimental support. In addition, the interacting effect of behavioral matching with physical anthropomorphism during human-robot interaction also lacks rigorous validation (Fig. 2).

C. Temporal correspondence

In the motor control literature, the basic structure of interpersonal coordination has been investigated using a now classic paradigm of inter-limb rhythmic coordination (e.g., [21]). A significant number of studies have found that the patterning of the relative phase angle (φ) of two participants rhythmically moving their arms together follow the predictions of nonlinear coupled-oscillator models, i.e., the existence of differentially stable symmetric relations, in-phase (φ close to 0°), and anti-phase (φ close to 180°), with a switch from the less stable anti-phase mode to the more stable in-phase mode as movement frequency increases. Research in this area has investigated whether such an informationally-based interpersonal entrainment can operate unconsciously in natural interactions, and has demonstrated that relative phase angles also concentrate around 0° and 180° when participants are not instructed to synchronize, or when they perform an explicit task while moving their limbs [22]-[23]. These studies suggest the existence of bi-directional information exchange during spontaneous coordination.

In scientific neurosciences, temporal correspondence has also been investigated through the concept of motor resonance, defined as the mechanism by which the neural substrates involved in both the execution of an action and the feeling of emotions, are also recruited when we perceive other individuals experiencing the same action or the same emotion [24]. While this concept can be traced back to the early days of psychology [25], its interest in the field of neuroscience and human-robot interaction has been renewed by the discovery of ‘mirror neurons’ in the ventral premotor cortex of the macaque monkey [26]-[27]. Mirror neurons are excited both when monkeys perform a goal-directed action and when they perceive (see or hear) the same action performed by an experimenter. Complementary neuroimaging studies have identified brain regions in human premotor cortices (e.g., [28]-[29]), in which action execution and observation overlap for a review, see [30]).

III. THE CLINICAL CONTEXT

The literature review detailed above suggests that all components of similarity — Physical resemblance, behavioral matching, and temporal correspondence — can contribute to increase social affiliation and connectedness during dyadic sensori-motor interaction. This hypothesis is of particular relevance for patients suffering from social deficits, as simple interpersonal coordination tasks can be used in the clinical context to improve social interaction. In the current categorical classification of mental disorders social interactions deficits are key symptoms of several disorders such as schizophrenia, social anxiety disorder and autism (DSM-IV-TR, APA, 2000). In schizophrenia (SCHIZ), patients manifest deficits in social competence. The dominant psychotherapy treatment is the social skills training (SST). It involves group techniques based on operant and social learning theory, with contradictory results [31]-[32]. In social anxiety disorders (SAD), SST is used to achieve a reduction of social anxiety, with here as well contrasting results [33]. In autism spectrum disorders (ASD), SST improves social and behavioural symptoms in children and adolescents [34], but its efficacy in the treatment of adults having ASD is controversial [35]-[36]. In sum, for the three types of social deficits (SCHIZ, SAD, ASD) group therapy using SST gives mixed results. In the AlterEgo project, we take the similarity theory as a starting point, and propose that a
similar alter ego (physical resemblance, behavioural matching, and temporal correspondence) will contribute to facilitate social interaction. We thus hypothesize that if a patient faces an artificial agent morphologically and behaviourally similar to her/him, s/he will increase his/her engagement in a social interaction.

IV. ALTEREGO IN FOUR STEPS

During the time course of the AlterEgo project, four chronological steps are envisaged.

A. First step: Similarity to launch interaction

Humans and avatars will play a mirror synchronization game, during which the social roles will be manipulated, from leader to follower to joint improvisation. To endow the avatar with the ability to perform the above task, a cognitive architecture will be designed, exploiting complex systems algorithms. Avatars will have the same morphology and the same movement characteristics as those of the patient, and we expect the mirror game to facilitate social interaction in patients.

B. Second step: From similarity to difference

Once the patient has achieved a sufficient level of coordination with the artificial agent, the avatar will be changed into someone different, in two complementary ways: physical resemblance and movement (behavioural matching and temporal correspondence). The avatar will be resembling, or moving like, either another human or a socially neutral agent (the avatar of the European iCub robot). From the patient’s perspective, the major challenge will be to maintain the same performance in the mirror game task while cooperating with a continuously changing avatar.

C. Third step: Direct Interaction

At this stage, different levels of interaction will be compared. Patient will move from interacting with robot/human avatars to interacting with the real iCub robot and a real human. The same synchronization game and the various leading/following conditions will be used.

D. Four step: Toward a rehabilitation protocol

During the final stage of the project, the similarity-then-different synchronization situation (step 1 to step 3) will be implemented in a longitudinal rehabilitation protocol. An evaluation task before and after the rehabilitation period will be performed in order to assess whether the quality of social interaction of the patients has increased.

V. FIRST RESULTS OF THE SIMILARITY EXPERIMENTS

Here we present the first results of two experiments performed with healthy patients during the first part of the project. These experiments have been conducted in order to test the effects of physical resemblance and behavioural matching on the stability of the coordination of two people interacting together.

A. Physical appearance affects socio-motor coordination

As detailed in section II, physical appearance, such as morphology, can affect social interaction, and the aim of this first study was to evaluate to what extent it can affect the patterns of movement produced by a human interacting with an artificial agent. The ‘artificial’ agent was a simple dot on a screen moving side-to-side at various frequencies, with on its top one of two pictures illustrated in Fig. 3: an un-preferred agent (NPA), and a preferred agent (PA). NPA and PA status were evaluated using a specific questionnaire prior to the experiment. Participants were engaged in a coordination game, in which they had to synchronize, using a hand-held cursor maintained on the tactile screen (Wacom tablet Cintiq 21), motion of the cursor-driven blue dot with the motion of a yellow dot. The yellow dot was animated with a simple computed-generated sinusoidal motion. The instruction was to maintain a stable synchronization either in-phase (φ close to 0°), or in anti-phase (φ close to 180°) with the yellow dot. Two different movement frequencies were tested: 100% of the natural (pre-recorded) participant’s frequency, and 150% of the natural frequency. Participants were free to move their eyes during the trial.

Because morphology influences our rapport with others [39], and because socio-motor coordination is know to be more stable when interacting with mentally-connected humans, we hypothesized that the stability of coordination would be lower in PA than in UPA conditions. Fig. 4 illustrates representative time series in the different conditions (top), together with mean data obtained from 20 participants (bottom). The results confirmed our hypothesis, showing a higher stability in PA rather than UPA conditions, particularly in anti-phase at 150% of the preferred frequency. This suggests a basic effect of physical preference on the fine motor control required to maintain a precise synchronization with an artificial agent.

These results suggest that the morphological similarity increases socio-motor performance. In order to better understand the processes underlying such beneficial effect, we now address another component of similarity, behavioral matching.

B. Behavioral matching affects socio-motor coordination

In our second experiment, the exposure of similarity over a long period of time and the way it affects our socio-motor competences was assessed using a pre-test / post-test design. With one exception [37], research in the field of socio-motor coordination has used simple and predictable movements, and mostly over short periods of time. Here we assessed the intentional motor coordination using free 1D movements with several frequencies and amplitudes. In this experiment we had healthy participants (N = 92) instructed to create interesting, various, and complex movements together [38] while staying synchronized. Different conditions were used: Leader-follower and Joint Improvisation. In the leader-follower condition, one designated participant had to lead the coordination while the second had to follow his/her movements. In joint improvisation, there was no designed leader: roles emerged naturally between the two participants.
Prior to the experiment, participants were randomly assigned into two groups: The similar group and the dissimilar group. The two groups differed in terms of exposure condition. Participants from the similar group were asked to perform movements with the same amplitude whereas in the dissimilar group, one participant of the dyad was instructed to produce a movement of small amplitude while the other produced a movement of large amplitude. For both groups, participants were asked to perform their movements at their own frequency while looking at the other participant’s movement.

Fig. 5 illustrates representative data obtained in the testing situations. We analyzed the accuracy and the stability of the coordination between the two members of the dyad for Leader/Follower and Joint Improvisation conditions. The complexity of the movements was also analyzed.

The experiment was thus composed of five steps: pre-test (PRE), exposure-1, intermediate-test (INTER), exposure-2, post-test (POST). The similarity (i.e., similar or dissimilar) was tested during the two exposure steps. Finally, before the pre-test and after the post-test, participants were also asked to rate their feeling of connectedness towards their co-actor.

Results revealed that exposure affected the synchronization performance differently for Leader/Follower and Joint Improvisation conditions. First, groups were not different at pre-test. Second, we observed a better synchronization after the exposure for the two groups in the Joint Improvisation condition. However, a comparison between pre- and post-tests revealed a decrease of the performance in Leader/Follower but only for the Similar Group. Third, the stability of the coordination in the Leader/Follower condition deteriorated after exposure-1 for the similar group.

In Joint Improvisation, the results revealed a loss of stability after exposure-1 associated with an increase of movement complexity. They also revealed an increase in stability after exposure-2 associated with a good and persistent level of complexity for both groups. Importantly, the dissimilar group exhibited a significant increase in coordination stability in Joint Improvisation after exposure-2. Fig. 6 summarizes the main results.

Finally, the analyses performed on the connectedness rating revealed a better affiliation after exposure-1 for the similar group, and the same trend for the dissimilar group but after the exposure-2.

Taken altogether, these results suggest that socio-motor competences can be acquired by introducing, in a social coordination situation, the following two consecutive steps: 1) perform a similar task to improve the coordination in Joint Improvisation and promote the sense of affiliation, followed by 2) a dissimilar task in order to improve the stability in Joint Improvisation while maintaining a high level of complexity and improving connectedness between participants.

VI. CONCLUSION AND PERSPECTIVES

Together, the first results of the morphology experiment and the behavioral matching experiment reveal that during socio-motor interaction 1) attractive qualities in the agent’s morphology positively modulates the coordination pattern during synchronization, and 2) performing a similar-than different synchronization task with a partner increases with
time connectedness. These results have consequences for the rehabilitation of patients suffering from social disorders, on both treatment and socio-economic grounds.

Virtual reality (VR) has been recognized as promising tool for assessment and treatment of mental illnesses [39]. VR aims to create a visual, auditory and sometimes multisensory environment enabling patients to be immersed and experience social interaction with virtual humans [40]-[41]. In schizophrenia, the use of an artificial agent has already proven to be useful to assess cognitive [42], emotional [43] and behavioral [44] characteristics of patients, to improve attention [45], daily living [46] and conversational skills [47]. In addition to these positive effects of VR, here we expect that the engagement of patients in simple synchronization tasks and with simple artificial agents can offer a complementary methodology to existing group therapy (e.g., the psychotherapy treatment is social skills training), in order to improve social competences and mental connectedness.

Schizophrenia is a disorder of relatively low prevalence, with a 1% lifetime risk. However, the care for this disorder consumes 1.6 to 2.6% of the total health care costs in western developed countries (e.g., [48], a number that increases continuously and becomes a major concern for European countries. In this context, even a small rehabilitation benefit of VR-based social treatments can have very positive socio-economic consequences, by reducing the number of consultations and hospitalization days, increasing the number of repetitions facing an artificial agent, and accelerating rehabilitation time.

Fig. 5. (A) – The task of motor synchronization used in the behavioral matching experiment, together with (B) representative time-series of the testing conditions. See text for details.

Fig. 6. Tests (Pre/Inter/Post) x Condition (Leader-Follower/Joint improvisation) interaction effect for each exposure group (Similar / Dissimilar). Top: Mean relative phase indicating the performance in terms of synchronization. Middle: Cross Spectral Coherence indicating the stability of the coordination between the partners. Bottom: Index of complexity indicating the quality of the motion’s structure performed by the two partners.

Currently under investigation in the AlterEgo project is the manipulation of several morphological and action-related features (attractive vs. unattractive, tall vs. short, healthy vs. unhealthy, etc…), as well as the testing of morphology and behavioral matching components in schizophrenic patients.

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