Towards Measuring Motor Resonance in Real-World HRI

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***Abstract*—Motor resonance has, in principle, considerable potential as a measure for assessing the quality of an ongoing interaction. However, the ways in which it is currently measured is impractical for applied scenarios, and none of the established measures can be calculated in or close to real time. We describe ongoing efforts to assess whether MR can be obtained in ecologically more plausible scenarios and discuss issues in need of clarification and the required methodological steps for moving towards real-time detection and measurement.**

I. Introduction & Background

Since the discovery of mirror neurons [1], experimental evidence indicates that human actors trigger human observers' motor control systems, which is referred to as motor resonance (*MR*). Studies in human-robot interaction (*HRI*) provided evidence that robots with joint structures similar to that of humans can trigger the same systems as long as the robots' movements follow velocity profiles that are biologically plausible [2], [3]. It has subsequently been hypothesised that MR has an important function in human interaction, yet the precise role it is ought to play is typically not spelled out. Chaminade et al. proposed that MR could be used as indicator for the "quality of interaction" [2] and was indicating "the extent to which an artificial agent is considered as a social inter-actor" [4]. If true, MR has considerable potential within HRI, for example as application-independent measure for detecting, and maybe predicting interactional breakdowns. In order to verify these claims and clarify the role of MR in human-human and human-robot interaction, we need to find ways to detect and quantify MR non-intrusively in or close to real time.

In HRI contexts, MR is typically quantified via one of three second-order measures that are deemed to be consequences of its presence: differences in spatial variation of movements (motor interference (*MI*)), priming-related differences in reaction time, and differences in the adaptation of movement speed (motor contagion (*MC*)). The relevant differences are group-based effect size estimates between conditions in which the model moves congruently and those in which it moves incongruently with respect to the observer's movements.

While the majority of HRI-based MR research in the past targeted the identification of essential or contributive factors for triggering the effect [2], [3], [5]–[8], we have started more recently to change the standard paradigm for MI towards ecologically more plausible conditions, with the long-term goal of measuring the effect in close to real time [9]. In this study, the intransitive (or object-less) vertical and horizontal waving motions of the standard paradigm were replaced with forth-back or left-right transitive *pick-and-place* actions on a table surface. The employed model was an iCub humanoid robot [10] which fulfils all of the aforementioned criteria for triggering MR. We found evidence for MR having occurred in participants' left-right movements and weaker evidence for the effect of top-down priming. However, stronger evidence was found for the occurrence of an unexpected inverse motor interference effect in participants' forth-back movements: interference appeared to be stronger in the congruent as compared to the incongruent movement condition. The ongoing study sketched in the present abstract builds up on this work in order to clarify open questions.

II. Methodology

The ongoing study is based on the one described in [9] and still uses a 2x2x2x2 mixed design but with the following differences: The factor *interaction mode* was exchanged against *movement speed*, while the factors *congruency*, *movement direction*, and *prime* were maintained. The change is motivated by the aim to measure two outcome measures simultaneously. In addition to motor interference, we attempt to measure participants' speed adaptions (*MC*). The robot executes its movements either *slowly* or *fast*, and we added baseline measurements of participants' arm movements (cf. [11]).

A second change is the addition of facial expressions and active gazing behaviour to the robot's repertoire for *positively primed* group. In the previous experiment, participants had either been told that the robot was watching them, or they had not been told anything in this regard (*positive social prime* vs. *no prime*). The robot, however, displayed the same behaviour in both conditions. Based on the obtained results we believe that the prime has been too weak, and we therefore decided to introduce robot watching behaviour for the *positively primed* group, and explicitly tell the *negative primed* that the robot was ignoring them (*positive* vs. *negative prime*).

A third change is the modification of the spatial layout during forth-back movements. We hypothesised that what we termed "inverse motor interference" effect earlier, may have actually been a spatial compatibility effect occluding or overpowering a potentially occurring motor interference (cf. [9], [12]). In order to reduce the efficacy of potential spatial compatibility effects we reposition participants during conditions involving *forth-back* movements: Participants and robot, while still sitting at opposite ends of the table, are positioned such that their right arms, rather then their heads, are aligned along the forth-back axis and when participants perform forth-back movements. We hope to have thereby neutralised any potentially occurring spatial compatibility effects by design.

III. Discussion & Outlook

If Chaminade's et al. assertion is correct and motor resonance does indeed track the quality of an ongoing interaction, the measure's potential value for HRI can hardly be overstated. At this moment, however, empirical support is yet to be provided. Independent of this claim, there are several other issues linked to MR. Theoretically the relationship between MR and related measure such as entrainment needs clarification (but cf. [13]). Methodologically, we have shown in [9] that the established ways of quantifying MI are not equivalent. Standardisation or, at least, agreement with respect to data processing choices for MI in particular is therefore needed. Furthermore the measured effect sizes of MI were small such that a further relaxation of experimental constraints may lead to a loss of detectability. A further methodological issue arises if we assume motor resonance to fluctuate within the course of an ongoing interaction. While MR is currently measured on the group-level, individual interactions will involve only few or even single persons. In order to detect motor resonance here "on the fly" statistical methods operating on individual time series such as change point predictions [14] will be needed.

We hope to be able to report initial results during the workshop. In the longer run we are planning to apply the above-mentioned methods for time series analysis to our existing motion recordings in order to explore the variability of the different second-order measures between individuals as well as to assess their volatility as the measurements unfold in time.

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