# Robot Dominance Expression Through Parameter-based Behaviour Modulation

Peters, Rifca; Broekens, Joost; Li, Kangqi; Neerincx, Mark

**DOI**
10.1145/3308532.3329456

**Publication date**
2019

**Document Version**
Final published version

**Published in**
IVA 2019 - Proceedings of the 19th ACM International Conference on Intelligent Virtual Agents

# Robot Dominance Expression Through Parameter-based Behaviour Modulation

Rifca Peters
Delft University of Technology
r.m.peters@tudelft.nl

Joost Broekens
Leiden University
d.j.broekens@liacs.leidenuniv.nl

Kangqi Li
Delft University of Technology
likangqi7893@gmail.com

Mark A. Neerincx
Delft University of Technology
m.a.neerincx@tudelft.nl

## ABSTRACT

A mayor challenge in human-robot interaction is the synthesis of social signals through non-verbal behaviour expression. Appropriate perception and expression of dominance (verticality) is essential for social interaction. In this paper, we present our work on algorithmic modulation of robot bodily movement to control dominance expression. We developed a parameter-based model for body expansiveness. This model was applied to a variety of behaviours and evaluated by human observers in two different studies with respectively static postures (N=772) and gestures (N=31). Modulation of body expansiveness proved to robustly influence perceived dominance independent of behaviour and viewing angles.

## CCS CONCEPTS

• **Human-centered computing → HCI theory, concepts and models**.

## KEYWORDS

social robotics, body language, dominance, non-verbal behaviour, expression, social signal, perception, synthesis, modulation

**ACM Reference Format:**
Rifca Peters, Joost Broekens, Kangqi Li, and Mark A. Neerincx. 2019. Robot Dominance Expression Through Parameter-based Behaviour Modulation. In *ACM International Conference on Intelligent Virtual Agents (IVA '19), July 2–5, 2019, PARIS, France.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3308532.3329456

## 1 INTRODUCTION

The need for the expression of social signals by robots and virtual agents is grounded in the believe that social capabilities improve human-agent interaction [12, 25]. An important interpersonal factor is dominance. Interaction stance can be represented in the interpersonal circumplex —Leary s Rose— a two dimensional model of dominance-submissiveness and affiliation-hostility [18]. In social signal processing this dominance dimension is referred to as *verticality* [24]. Dominance is also a dimension of affect, emotions can be depicted in a multidimensional pleasure, arousal and dominance (PAD) model [22].

Human behavioural cues that are used for dominance expression include increased body expansiveness [6, 11], forward, upright and oriented towards posture [7], and upward head tilt [7, 21]. Further, specific gestures have been linked to dominance expression, for example, pointing [1]. To the best of our knowledge, the exact relation between motion performance and dominance expression is unknown.

A common approach for emotional expressions of virtual agents is to design specific behaviours based on human behaviour [12]. Facial expressions are a predominant cue [16], but often unavailable for humanoid robots. Emotional expressions were proven possible with bodily features as well [10, 13]. Alternative to laborious behaviour design, parameter-based transformations have been explored (e.g., [19, 26]), however, these methods still require a considerate amount of work. Development of one modulation pattern applicable to existing behaviours improves the flexibility of parameter-based transformations.

This paper presents a model with one modulation pattern (i.e., body expansiveness) for dominance expression, and the results of the perception study of the concerning expressions.

## 2 RELATED WORK

Interest in synthesis of expressive behaviour is growing. Specifically, dominance expression was subject of research before.

Some investigate the human perception of specific behaviours (e.g., [4, 8]), classes of behaviours (e.g., [2, 14]), or behaviour sequences [9]. This line of work may indicate appropriate behaviours, but not how to perform them; it gives no insight in the features of the behaviours that convey the expression. Further, behaviours are often created for a specific purpose, it is unclear whether effects are valid in other systems with a different embodiment and/or function.

Studies on performance parameters report, for example, a positive relation between dominance and forward motion [15, 23], forward gaze [3], head tilted upward [3, 17, 20], and posture openness [14]. However, the latter modified multiple parameters in parallel, making it impossible to conclude effects for unique parameters. Xu [26] found no effect on perceived dominance for parallel manipulation of, amongst others, gesture size, motion speed, and head position. This does not mean that neither parameter had an effect, only combined potential effects were not perceptible. Contradicting results occurred also between studies testing single parameters. For example, Kim [15] reported a positive effect for motion speed


*IVA '19, July 2–5, 2019, PARIS, France*

ACM ISBN 978-1-4503-6672-4/19/07.
https://doi.org/10.1145/3308532.3329456

on dominance, while Saerbeck [23] found a negative effect. Most likely the robot's embodiment, (limited) selection of behaviours, and scenario are moderating factors.

A limitation of prior studies is that findings are often context, or behaviour specific and have limited value for future agent design. Therefore, we focus on identifying the effect of a generic parameter, *body expansiveness*, on perceived dominance for a range of behaviours.

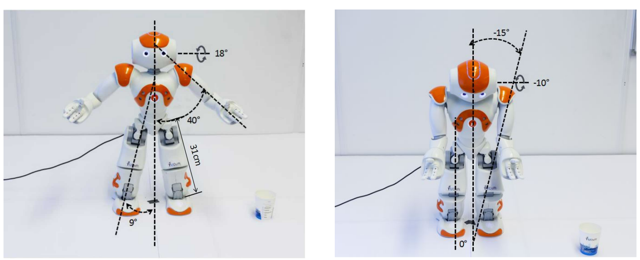
# 3 ROBOT DOMINANCE MODEL

Based on human behavioural cues, we created a parametric model of body expansiveness for dominance expression by a NAO robot.

First, we specified the generic body expansiveness manipulation. An expanded body shape relates to dominance display, whereas an enclosed shape signals submissiveness. To manipulate body expansiveness, and thereby dominance expression, the following parameters were adjusted: vertical head angle, horizontal shoulder angle, horizontal and sagittal hip angle, and vertical leg stretch. Transformations applied onto a base position are: for maximum dominance, head tilt 18°, shoulder angle 40°, leg angle 9° and leg stretch 30cm (Fig. 1a); and for maximum submissiveness, head tilt -10°, shoulder angle 10°, leg angle 0° and leg stretch 26.5cm (Fig. 1b).

Next, we implemented this model on a NAO robot. Linear joint modulations are applied relative to the original movement trajectory and proportional to the dominance level $[-1.00, 1.00]$. Affected joints and NAO specific adjustment patterns are given in Table 1.

Space limitations do not allow us to explain the computational model in more detail here.




**(a) spreading/dominant** **(b) enclosed/submissive**

**Figure 1: angle adjustments from a neutral standing pose.**

**Table 1: affected joints and angle adjustments for max. dominant, neutral and max. submissive stance.**

| Parameter | Joint | Dom (1) | Neutral (0) | Sub (-1) |
|---|---|---|---|---|
| *Head tilt* | `HeadPitch` | 0.51 | 0.00 | 0.67 |
| *Shoulder angle* | `LShoulderRoll` | 1.33 | 0.00 | -0.31 |
| *Leg angle* | `LHipYawPitch` | -0.17 | 0.00 | 0.00 |
| | `LHipRoll` | 0.09 | 0.00 | 0.00 |
| *Leg stretch* | `LHipPitch` | 0.13 | 0.00 | -0.44 |
| | `LKneePitch` | -0.08 | 0.00 | 0.69 |
| *Stability correction* | `LAnklePitch` | 0.08 | 0.00 | -0.35 |
| | `LAnkleRoll` | -0.13 | 0.00 | 0.00 |

# 4 VALIDATION

In two consecutive perception studies we validated whether changes in body expansiveness as presented in Section 3 influenced observers' perceptions of dominance expressed by a robot.

## 4.1 Postures

*Method.* We conducted a 2 (expansiveness) × 2 (horizontal angle) × 2 (vertical angle) between-subject, factorial perception study to evaluate the effect of posture expansiveness on perceived dominance. For this, we prepared 88 pictures of 11 distinctive postures performed by a NAO robot (SoftBank Robotics, France), taken from a 0° and 30° horizontal angle and with the robot on ground level and a table. Further, we created an on-line survey at Amazon Mechanical Turk. A total of 772 participants (aged 20–83, 60% male) viewed and rated (on a 5-point bipolar scale) one by one the 11 pictures in the assigned condition.

*Results.* A repeated measures MANOVA revealed a significant main effect for body expansiveness on perceived dominance, $F = 262.52, p < 0.001$, and a small, positive, interaction effect for vertical view angle × expansiveness on perceived dominance, $F = 9.79, p = 0.002$. In other words, overall participants perceived the robot with spreading postures as more dominant ($\mu = 3.26, Std = 0.44$) than the enclosed postures ($\mu = 2.69, Std = 0.54$), and this effect was stronger for a robot standing on a table compared to ground level (Fig. 2). This shows that our body expansiveness manipulation affected perceived dominance in the desired direction consistent over multiple postures and viewing angles.

## 4.2 Synthesised Gestures

*Method.* We conducted a multivariate test with between-subject variable body expansiveness, and within-subject variable gesture to evaluate the effect of gesture expansiveness modulation on observers' perceptions of the robot's dominance display. First, we selected 10 behaviours designed as neutral expressive and with various functions. And we developed software for real-time modulation following Section 3. For the purpose of this experiment, we displayed the original and the maximum high and low dominance modulated behaviours on a physical NAO robot. A total of 31 participants (aged 23–62, male=17, female=14) observed 10 gestures each in the assigned condition (i.e., original/neural, spreading/dominant, or enclosed/submissive) one by one and for each completed the Self Assessment Manikin (SAM) questionnaire [5], measuring dominance, valence and arousal on a 9-point Likert scale.

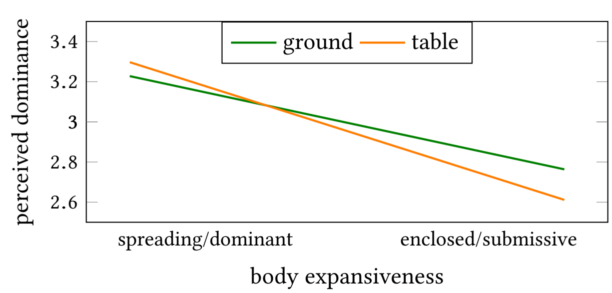



**Figure 2: mean perceived robot dominance (range [0, 5])**

*Results & Discussion.* Using Pillai's trace, the multivariate test showed a moderate tendency of body expansiveness to affect overall perception, $V = 0.35, F(6, 54) = 1.90, p = 0.098$. However, separate univariate ANOVAs on the outcome variables revealed significant positive body expansiveness effects on perceived dominance, $F(2, 28) = 4.41, p = 0.022$; and arousal, $F(2, 28) = 5.10, p = 0.013$. In other words, overall participants perceived the robot displaying spreading gestures as more dominant ($\mu = 5.6$) and aroused ($\mu = 5.93$) than a robot showing enclosed gestures (dominance, $\mu = 4.58$; arousal, $\mu = 4.76$), and perceived valence was not affected by the body expansiveness modulation. This means that parameter-based modulation of expansiveness successfully moderated dominance expression for various gestures. Further, normalising and comparing measures from both studies there is no difference in perceived dominance between postures (spreading, $\mu = 0.65$; enclosed, $\mu = 0.54$) and gestures (spreading, $\mu = 0.6$; enclosed, $\mu = 0.51$). This means that the expansiveness modulation effect is behaviour as well as modality (gesture versus posture) and embodiment (real versus picture) independent.

## 5 CONCLUSION

We have shown the validity of body expansiveness modulation for dominance expression in both postures and gestures. We show that with a limited set of parameters we can moderate dominance expression.

Body expansiveness has been manipulated by the parameters head tilt, shoulder angle, leg angle, and leg stretch. Consistent modulation of these parameters influences perceived dominance in the intended direction for various postures and gestures.

Although the joint angles are specific to the NAO robot, the body expansiveness modulation can be applied to any humanoid robot or embodied agent. This makes our method applicable to other systems and scenario's as well, although the perception effects we report should be verified with other robots.

These studies provide evidence that body expansiveness is an important factor for dominance expression and that this effect is behaviour independent and independent of view angle.

## ACKNOWLEDGMENTS

This work is supported by the EU Horizon 2020 PAL project (grant nr. 643783).

## REFERENCES

[1] Michael Argyle. 2013. *Bodily communication.* Routledge.
[2] Amy L Baylor and Yanghee Kim. 2005. Simulating instructional roles through pedagogical agents. *Int. J. of Artificial Intell. in Edu.* 15, 2 (2005), 95–115.
[3] Aryel Beck, Lola Cañamero, and Kim A Bard. 2010. Towards an affect space for robots to display emotional body language. In *Proc. 19th Int. symp. in robot and human interactive commun.* IEEE, Viareggio, Italy, 464–469.
[4] Aryel Beck, Brett Stevens, Kim A Bard, and Lola Cañamero. 2012. Emotional body language displayed by artificial agents. *Trans. on Interactive Intell. Syst.* 2, 1 (2012), 2.
[5] Margaret M Bradley and Peter J Lang. 1994. Measuring emotion: the self-assessment manikin and the semantic differential. *J. of behavior therapy and experimental psychiatry* 25, 1 (1994), 49–59.
[6] Dana R Carney, Amy JC Cuddy, and Andy J Yap. 2010. Power posing: Brief nonverbal displays affect neuroendocrine levels and risk tolerance. *Psychological sci.* 21, 10 (2010), 1363–1368.
[7] Dana R Carney, Judith A Hall, and Lavonia Smith LeBeau. 2005. Beliefs about the nonverbal expression of social power. *J. of Nonverbal Behavior* 29, 2 (2005), 105–123.
[8] Ginevra Castellano, Maurizio Mancini, Christopher Peters, and Peter W McOwan. 2012. Expressive copying behavior for social agents: A perceptual analysis. *Trans. on Syst., Man, and Cybern.* 42, 3 (2012), 776–783.
[9] Mathieu Chollet, Magalie Ochs, and Catherine Pelachaud. 2014. From non-verbal signals sequences mining to bayesian networks for interpersonal attitude expression. In *Proc. Int. Conf. on Intell. Virtual Agents*, Vol. 2792. Springer, Boston, United States, 120–133. https://doi.org/10.1007/b12026
[10] Iris Cohen, Rosemarijn Looije, and Mark A Neerincx. 2014. ChildâĂŽs perception of robotâĂŽs emotions: effects of platform, context and experience. *Int. J. of Social Robot.* 6, 4 (2014), 507–518.
[11] Amy JC Cuddy, Caroline A Wilmuth, Andy J Yap, and Dana R Carney. 2015. Preparatory power posing affects nonverbal presence and job interview performance. *J. of Appl. Psychology* 100, 4 (2015), 1286.
[12] Terrence Fong, Illah Nourbakhsh, and Kerstin Dautenhahn. 2003. A survey of socially interactive robots. *Robot. and autonomous syst.* 42, 3-4 (2003), 143–166.
[13] Wafa Johal, Sylvie Pesty, and Gaëlle Calvary. 2014. Expressing Parenting Styles with Companion Robots. In *Workshop on Applications for Emotional Robots.*
[14] Wafa Johal, Sylvie Pesty, and Gaelle Calvary. 2014. Towards companion robots behaving with style. In *Proc. 23rd Int. Symp. on Robot and Human Interactive Commun.* IEEE, Edinburgh, Scotland, 1063–1068.
[15] Jaewook Kim, Sonya S Kwak, and Myungsuk Kim. 2009. Entertainment robot personality design based on basic factors of motions: A case study with rolly. In *Proc. Int. Symp. on Robot and Human Interactive Commun.* IEEE, Toyama, Japan, 803–808.
[16] Daisy N Kurien. 2010. Body language: Silent communicator at the workplace. (2010).
[17] Brent Lance and Stacy C Marsella. 2007. Emotionally expressive head and body movement during gaze shifts. In *Proc. Int. Conf. on Intell. Virtual Agents*, Vol. 2792. Springer, 72–85. https://doi.org/10.1007/b12026
[18] Timothy Leary. 1958. Interpersonal diagnosis of personality. *Amer. J. of Physical Med. & Rehabilitation* 37, 6 (1958), 331.
[19] Yueh-Hung Lin, Chia-Yang Liu, Hung-Wei Lee, Shwu-Lih Huang, and Tsai-Yen Li. 2009. Evaluating emotive character animations created with procedural animation. In *Int. Workshop on Intell. Virtual Agents.* Springer, Amsterdam, The Netherlands, 308–315.
[20] Brian Ravenet, Magalie Ochs, and Catherine Pelachaud. 2013. From a user-created corpus of virtual agent's non-verbal behavior to a computational model of interpersonal attitudes. In *Proc. Int. Conf. on Intell. Virtual Agents*, Vol. 8108 LNAI. Springer, 263–274. https://doi.org/10.1007/978-3-642-40415-3_23
[21] Nicholas O Rule, Reginald B Adams Jr, Nalini Ambady, and Jonathan B Freeman. 2012. Perceptions of dominance following glimpses of faces and bodies. *Perception* 41, 6 (2012), 687–706.
[22] James A Russell and Albert Mehrabian. 1977. Evidence for a three-factor theory of emotions. *J. of res. in Personality* 11, 3 (1977), 273–294.
[23] Martin Saerbeck and Christoph Bartneck. 2010. Perception of affect elicited by robot motion. In *Proc. Int. Conf. on Human-robot interaction.* IEEE, Osaka, Japan, 53–60.
[24] M. Schmid Mast and J. A. Hall. 2017. *Social signal processing.* Cambridge University Press, Cambridge, Chapter The vertical dimension of social signaling, 34–45.
[25] A. Vinciarelli, M. Pantic, D. Heylen, C. Pelachaud, I. Poggi, F. D'Errico, and M. Schroeder. 2011. Bridging the Gap Between Social Animal and Unsocial Machine: A Survey of Social Signal Processing. *Affect. Comput.* 3, 1 (2011), 69–87.
[26] Junchao Xu, Joost Broekens, Koen Hindriks, and Mark A Neerincx. 2014. Effects of bodily mood expression of a robotic teacher on students. In *Proc. Int. Conf. on Intell. Robots and Syst.* IEEE, Chicago, Illinois, 2614–2620.