Are Robots That Assess Their Partner's Attachment Style Better At Autonomous Adaptive Behaviour?

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***Abstract*—Interacting with partners that understand our desire of closeness or space and adapt their behavior accordingly is an important factor in social interaction, since the perception of others is a fundamental prerequisite for reliable interaction. In human-human interaction (HHI), this information can be inferred by a person's *attachment style* - a person's characteristic way of forming relationships, modulating behavior (i.e ways to give or seek support) and, on a biological level, their hormone dynamics. Enabling robots to understand their partners' attachment style could enhance robot's perception of partners and help them on how adapt behaviors during an interaction. In this direction, we wish to use the relationship between attachment style and cortisol, to equip the humanoid robot iCub with an internal cortisol-inspired framework that allows it to infer the participant's attachment style and drives it to adapt its behavior accordingly.**

***Index Terms*—adaptation, human-robot-interaction, attachment style, hormonal motivation**

I. Introduction

Attachment styles in people predict and reflect how we think, feel and behave in close relationships, as well as how we perceive our partners, regulate our emotions, and give and seek out support [1]. A person's attachment style represents their attachment security or insecurity, based on their expressed levels of *anxiety* and *avoidance* in relationships [2]. The combination of these two dimensions produces four prototype adult attachment styles (as shown in Table I): *secure attachment* (low anxiety/low avoidance) and three insecure styles, *preoccupied* (high anxiety/low avoidance), *dismissing* (low anxiety/high avoidance) and *fearful* (high anxiety/high avoidance) [3].

TABLE I
Adult Attachment Styles

	Low Anxiety	***High Anxiety***
Low Avoidance	Secure	Preoccupied
High Avoidance	Dismissing	Fearful

Attachment styles develop around our first year of life, and are strongly influenced by our relationship with our parents and caregivers [2], [4]. In infants, the attachment styles are slightly diverse from the adult ones, and are classified as: secure, ambivalent/anxious, avoidant, and disorganized [2]. These infant attachment styles are corresponding to the adult styles as follows: secure - secure, ambivalent/anxious - preoccupied, and avoidant - dismissing [5]. The disorganized style of infants can be related to all insecure adult attachment styles. On the biological level, the attachment style is reflected directly in the hypothalamic–pituitary–adrenal (HPA) axis activation [6], [7]. For instance, after experiencing the same stressful situation, people with any insecure attachment style report higher cortisol levels than secure people [8], [9]. This is due to the fact the people with different attachment styles experience differently the same stressors (i.e. by some people a stimulus may be perceived as a stressor, while by others not), resulting to an increase or decrease of cortisol levels. Moreover, during friendship initiation, strangers with a match in attachment styles have lower cortisol levels than strangers with a mismatch in attachment styles, which leads to more pleasant interactions [10]. This underlines the importance of interacting with a partner that has a similar perception of closeness and space as ours, and whose consequent behaviour is not considered as a stressor.

This is a relevant issue also in human-robot interaction (HRI): if we wish to see robots become effective interaction partners, they will need to adapt their behavior according to the human partner's needs and affective states [11]. One approach towards this goal could be through enabling the robot to understand the participant's attachment style during the interaction, and adapt its behavior to it [12], [13] (Fig. 1).

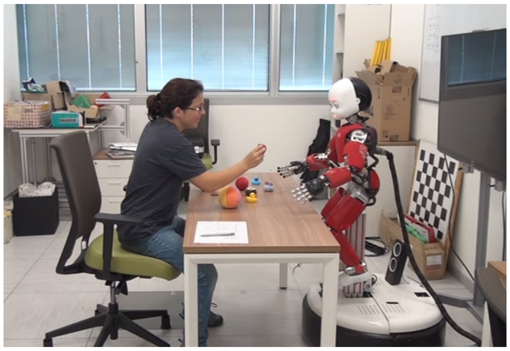

Fig. 1. Image shows a person seated at a table, opposite a standing robot. The robot is the iCub humanoid robot. The person has a selection of toys on the table in front of them, and is holding up one in front of iCub, interacting with it. The robot is looking at the toy with a smiling expression.

II. MOTIVATION

In our research, we are drawing inspiration from different studies on human-human interaction (HHI) focusing on the relationship between cortisol and attachment style. We port the derived models into HRI studies, by starting from existing research dedicated to the modelling of hormonally-inspired internal drives in robotics [14]–[16]. From there, we aim to endow the humanoid robot iCub [17] with a internal motivation drive utilizing cortisol as a modulator. This hormonally-inspired framework will be utilized to enable iCub to understand the human partner's attachment styles by the effect the interaction will have on its motivation framework.

Starting from findings in literature, we pose our hypothesis that the cortisol level is representative of the participant's attachment style, and more specifically that during human-robot interaction (as it happens also during human-human-interaction), a mismatch in the expressed attachment style between a participant and a robot will cause higher cortisol levels in the robot than a match in attachment style [10], [18], [19].

We wish to design two robotic behavioral profiles portraying two attachment styles (one high in the avoidance dimension, and the other high in the anxious one). In order to verify our hypothesis, we will be using the robot's internal cortisol level as a possible mirror of participant's cortisol level. Our expectation is that a secure person will be able to interact well with both robot profiles due to their ability to understand the robots' need in both conditions, and in this case robot's cortisol level will be low. On the other hand, we expect that a preoccupied or a dismissing person will have interaction compatibility only with the robot in the same attachment style (since they may share the same needs or attitudes), causing an increase of robot's cortisol level with the mismatching attachment style. Relying on the relation between cortisol, attachment styles and their typical behaviors, and the effects of match/mismatch in them, we aim to enable the robot to understand the participant's attachment style.

The first part of our research will be centered around modelling cortisol mechanisms representative of the different attachment styles, reproducing the typical behaviors of an attachment style both in stressed and unstressed conditions, and identifying the best parameters and stimuli to simulate an attachment style.

After the validation of our cortisol model (explained in Section 3.1), we will evaluate its performance during an human-robot interaction (Section 3.2); in particular we will test whether participants behave differently with a robot with different attachment styles, whether they have preferences for one of them, and whether their behavior is predictable knowing in advance their attachment style.

Moreover, we will investigate if the robot's cortisol dynamics recorded during the interaction reflect the person's attachment style. Through this part of the research we want to evaluate the existence of an attachment style in human-robot interaction, if it coincides with the one in human-human-interaction, and if a match in attachment style during a HRI can improve the interaction.

Considering the obtained results, in the next studies our cortisol framework will be used to detect human attachment style and to drive a robot in its autonomous behavior in an adaptive way toward the partner.

III. COGNITIVE FRAMEWORK WITH HORMONAL MODULATION

To study in a more structured manner how the motivational mechanism rooted in cortisol changes during HRI, we are implementing a cognitive framework for our robots that will provide them with the primary supportive functionalities necessary for the HRI studies. The framework (as illustrated in Figure 2) consists of the following modules and their functionalities: a *perception* module processing tactile and visual stimuli; an *action* module, responsible for the robots' movements; and a *motivation* module, containing the cortisol-inspired internal motivation.

The perception module is processing stimuli from two sensor groups of the robot: *tactile stimuli* — the data processed from the skin sensor patches on the robot's arms and torso (carrying information about the size of the touched area and average pressure of the touch); and *visual stimuli* — the images coming from robot's cameras situated in its eyes (which are analyzed for detecting the presence of a person's face, extracting the facial expression of the person, and detecting the potential mutual gaze).

The action module performs a finite set of actions by controlling the specific body parts in the joint space (the robot's neck, torso and arms). The first experimental studies (as covered in Section 3.2) will focus on loosely replicating the results from human child-caretaker studies, where the robot will be in the role of a toddler. The robot's childlike role is essential for the replication of the human child-caretaker studies, and this is further assisted by iCub's childlike appearance; as such, the set of actions performed by it are limited to simpler behaviours like turning the torso towards the participants,

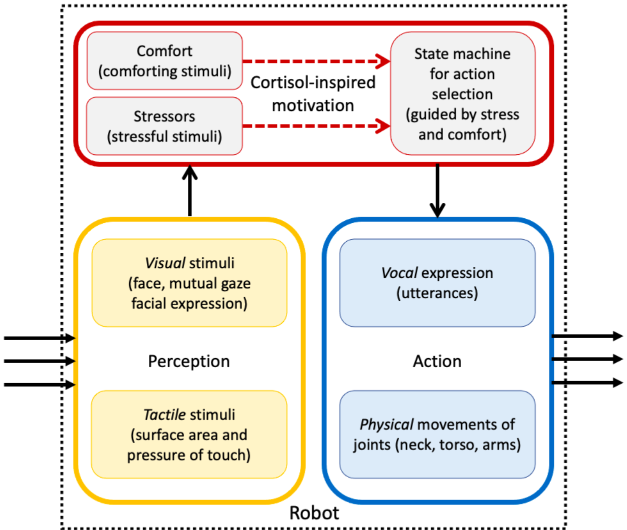

Fig. 2. Three main components of the framework - Perception, Action and Motivation. Perception component receives and processes Visual stimuli and Tactile stimuli. Visual stimuli consist of detection of face, facial expression, and presence of mutual gaze. Tactile stimuli consist of surface area of the touch and intensity or pressure. Action component sends the Vocal and Physical expressions of the robot. The vocal expression represents the robot's utterances. The physical expression are the movements of the robot's body parts - neck, torso and arms. The motivation component analyzes the received data from the Perception component and sorts it in two categories - Comforting stimuli and Stressful stimuli. These two categories are analyzed in the cortisol-inspired motivation module and are sent to the State Machine that guides the action selection process for the robot, which is then connected to the Action component.

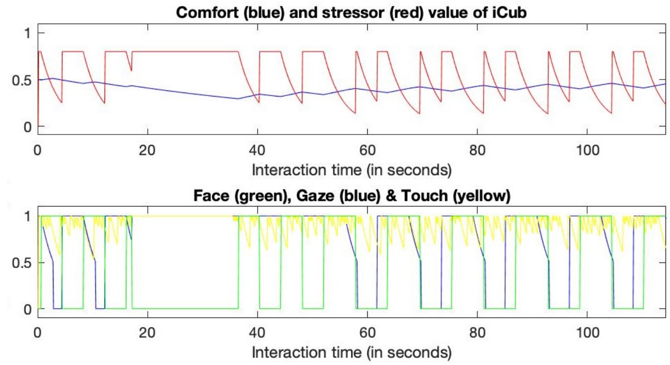

Fig. 3. Two graphs - upper graph shows the trend of the robot's comfort and stress levels, the lower graphs shows the stimuli received from the robot - facial expression, mutual gaze and touch. The graphs represent one full iteration of the Still Face paradigm. When there is a discrepancy between the stimuli - the robot receiving tactile stimuli but no facial information - the stressors are more constant.

stretching arms with open hands towards them with a smiling face to seek contact and attention or calling out vocally to them. Although these are fairly simplistic behaviours, in the context of HRI they have proven effective in as shown in our previous studies [14], [20].

The motivation module contains our proposed cortisol-inspired internal framework. The framework is loosely inspired by previous studies in HRI with hormonally-based internal motivations for the robot [14]–[16], where the robot's internal state changes as a function of the perceived change in the person's affective state, or the actions performed by the human partner. Our framework processes the visual and tactile stimuli received by the human to update the stress and comfort levels, which in turn directly influence the cortisol level (an illustration of this is given in Figure 3). Then, before performing an action, the robot relies on its cortisol levels and its current behavioral state to guide its behaviour and select its next action. In this phase we designed two robot profiles, one in avoidant and one in anxious attachment style; they react in a different way to same stimuli and have different cortisol patterns.

IV. Methodology

In our work, we aim to answer several research questions connected to the hormonal framework and how it is perceived by the people with whom the robot will interact. Namely we wish to investigate whether different attachment styles expressed in a robot are easily distinguishable by a person interacting with the robot, as well as whether a cortisol model of motivation in robots with different attachment styles will express differently.

A. Validation study

The first step following the completed implementation of the cortisol-inspired framework will be to perform a validation study. The purpose of the study will be to verify the different attachment profiles and the cortisol model, and it will consist of replicating a well-known paradigm in hormonal studies in HHI between mothers and infants: the Still-Face Paradigm (SF) [21]. The typical SF paradigm consists of three brief episodes structured in an A-B-A sequence [22]. The *first "A"* corresponds to the Play episode, where mothers and infants interact in a normal dyadic interaction setting. The *"B"* corresponds to the Still-Face episode, in which mothers are asked to become unresponsive and maintain a neutral facial expression. During this phase a socio-emotional stress is elicited by the experimental manipulation of maternal responsiveness and availability to interact. The *second "A"* is the Reunion episode, where mothers and infants restart normal interaction; it is a context of socio-emotional stress recovery.

Several studies used a modification of the SF paradigm that includes maternal touch during the SF episode (SF+T) and examined the differential effects of touch versus no-touch conditions on infant behaviors [23]. The comparison shows lower cortisol levels in infants in SF-T condition, pointing to a more attenuate response. Moreover, cortisol decreased at recovery for the SF-T condition and it markedly increased for SF condition indicating continued stress during reunion [24].

To facilitate the conducting of repeated trials during the validation study (for the process of fine-tuning the cortisol model), we prerecorded six sets of human stimuli, 2 conditions x 2 human profiles - control, avoidant and anxious profiles, and the still face and still face + touch. These stimuli sets will be used during the process of fine-tuning the parameters of the cortisol-based motivation, with the goal of obtaining the same results present in HHI literature.

B. Comparative interaction study

Our follow-up study will aim to test the two robot attachment profiles in a free-form interaction with naive participants. This is envisioned as a comparative study of free-form HRI, where naive participants will interact with two iCub robots equipped with the two extreme attachment styles. In the study the participants will assume the role of caretakers for both robots, whereas the robots will be in the role of toddlers.

Before the experiments, participants will be required to compile two questionnaires: the Adult Attachment Interview (AAI) [25] (to identify their attachment style), and the Robotic Social Attributes Scale (ROSAS) [26] (to evaluate their relationship with technology). The information we collect on their attachment style will later be compared with the one detected by iCub during the experiment. Additionally, in order to assess a possible correlation to their attachment style, we also collect the participants' age, biological sex, gender identity, and parental status.

In the experimental setup, the iCub will be positioned in front of a table, while participants will be seated near the robot and will have access to a box of toys to interact with it. During this phase, the robot behavior will be fixed and preprogrammed, so to guarantee the same robot reply in each stimuli. This choice is necessary to answer to the first research questions:

- Q1. How do participants perceive the robot and are they able to identify differences between the two profiles?;
- Q2. Is there a specific attachment style present for HRI? If so, which is the relationship with the ones present in HHI?.

During this experiment we will test our cortisol framework, which will be actively connected to the perception module and changing accordingly, but it will not be connected to the decision making module (i.e. the robot's behaviour will not be influenced by its cortisol levels). The findings of this experiment will be used to answer the last research question:

- Q3. Is the cortisol measure a good one-dimensional descriptor of attachment style?

Considering these results, we will proceed with a second experiment in order to test autonomous robots that act using their internal cortisol-framework. We will reproduce the same previous experiment conditions in order to compare the results obtained using preprogrammed robots behavior with the autonomous ones.

Lastly, we will use the collected findings and information to design a robot that acts following its internal cortisol-framework with the motivation to maintain its cortisol levels low. In this case, cortisol dynamics both act as an "attachment style detector" - if they are high there is a mismatch in attachment style, whereas if they are low there is a match (or the interaction is going well) - and as a drive to guide the autonomous behavior in an adaptive way towards the partner.

V. Discussion

Our research goal is to equip the humanoid robot iCub with an internal cortisol-inspired motivation that allows it to understand the participant's attachment style. At the same time, this hormonal motivation will drive the robot in adapting its behaviors and actions according with the person's perceived attachment style, in order to improve and personalise the interaction. Through this research we want to: investigate the existence of an attachment style in human-robot interaction and its relationship with the one in human-human interaction; discover if an internal cortisol measure can reflect participant attachment style; and understand how robots, designed with different attachment styles, are perceived by people. In particular we also investigate if during an interaction a match in attachment style between human and robot can lead to improved and enhanced interaction.

The next step in this work is the evaluation of our framework in a free-form interactive scenario with iCub. We will assess if our cortisol-based motivation can help in understanding the human attachment style, and if this information can be useful to enhance a human-robot interaction. We hope that by allowing the robot to understand a person's attachment style and have a mirror of it in its own motivational system, it will be able to better adapt its behaviour to the changes in the person's predisposition, leading to a more natural, adaptive interaction between humans and robots.

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