Integrating neuroimaging methods and neurohormonal measures for assessment and benchmarking of effective social bonding in HRI

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One of the primary goals in the Human-Robot Interaction (HRI) field is to be able to design and develop robots that can engage effectively when interacting with humans. As the use of autonomous agents in everyday life has been growing, significant research has been focused on understanding the social bonding between the user and the agent. Social bonding increases the trustworthiness and reliability of the robot from the user's perspective, even enabling closer psychological and physical proximity [1]. HRI research commonly employs the use of subjective and behavioral measures such as questionnaires and surveys to evaluate the user's degree of social bonding to the robot. While these measures are good at assessing the user's behavior after the moment of social affiliation, they lack the ability to capture the user's social bonding behavior in the moment of affiliation and can be dampened through the user's social inhibition. Neuroimaging and neurohormonal measures can provide unique neuroscientific information about the user's social bonding behavior at the moment of interaction, which can enrich the understanding of unique mechanisms behind the user's reactions [2]. We argue that measuring these neural correlates alongside traditional behavioral and subjective measures can offer a complementary approach to current HRI methodology with the potential to capture information beyond traditional methods. We believe that future HRI theory development may benefit greatly from an integrated neuroscientific measurement approach.

For the assessment of effective social bonding in HRI is that adding neurocognitive and neurobiological measures can provide a good comparison between social human-human and human-robot interactions. Neurocognitively, in human-human interaction, previous studies show that there is a relationship between increased electrical and hemodynamic brain activity and increased social bonding with the partner [3, 4]. Neurobiologically, some hormones such as oxytocin are related in regulating social behavior and social bond formation in partners regarding trust in human-human pairs [5, 6]. Using these methods together in HRI research similar to human-human interaction research together [7, 8] can enable the comparison between the person's behavior when affiliating with a human and with a robot. Understanding this comparison can indicate the factors that make human-robot bonding similar to human-human bonding.

Brain activity may also be useful as a social intent detector metric that can be used to gauge the social effects of human-robot interactions because brain areas regarding social cognitive processes activate based on the interaction [9, 10]. Therefore, monitoring brain activity can provide valuable information about the user's cognitive response in a social bonding scenario with a robot. Portable and wearable brain activity monitoring methods such as fNIRS and EEG have improved significantly over the last decade in terms of hardware, software, and algorithms for effective mobile brain/body imaging [11]. With recent advancements, these methods are now readily available for use in unencumbered, real-world dynamic environments such as monitoring the brain activity of participants walking outdoors [12] and pilots in the cockpit flying an aircraft [13]. While brain activity can explain the user's cognitive behavior, having only neurocognitive information may not be enough. By evaluating neurohormonal activity, we can examine the user's affective and social affiliative processes, willingness to trust and subconscious behavioral preferences [14]. Examining both neurocognitive and neurohormonal measures jointly offer the potential to broaden the understanding of human bonding and social affiliation beyond using either approach individually.

In conclusion, considering the points mentioned above, examining neurocognitive and neurohormonal measures alongside traditional HRI behavioral and subjective measures can enhance the understanding of the user's social bonding behavior during interaction since these modalities provide valuable information about the neural reactions of the user to the robot. Grasping the user's neural mechanisms and rationale behind the user's social bonding behavior in the moment of affiliating with a robot can provide supportive information in determining the factors that make the interaction most effective, which is beneficial for social robot design. Including these metrics into future standards of HRI measurement will be essential for improving the description of mechanisms in theories of HRI.

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