Emotion-Motion Interaction as a baseline for understanding non-verbal expression of computational empathy and user expectations*

Naomi Yvonne Mbelekani

***Abstract*—Most studies have explored user empathy towards robots, however, there is a lack of studies that explore emotional empathetic responses and reactions from a robotic arm. An argument is therefore presented on the use of emotions in a robotic application, focusing on the ability to convey emotional information through motion and empathy, i.e. reading emotional information from motion. The study purpose was to describe robot motion as an expression of emotion (empathy). A small use study is presented where the effect of one factor of motion, namely speed, on the empathic perception in humans is investigated. An experiment was conducted to examine the reaction and response of participants regarding the expression of emotion through the movement of a robotic arm. Since it's a preliminary study, four participants were randomly recruited. Results reveal an interplay between emotion and motion as baselines for understanding non-verbal expressions of empathy by a robotic arm, as well as users' expectations towards the robot. The concept discussed in this study is very relevant to advancing the quality of human-robot interaction (HRI).**

I. Introduction

Robots are becoming faster, cheaper, capable, and more flexible in performing different tasks and more interactive with humans [11]. As social robots are a trending field within HRI, there is a rapid need for them to be socio-emotionally intelligent (acquire social skills). As a result, affective computing consists of applying emotions to a robot, giving it the ability to recognize and express them, developing its ability to respond intelligently to human emotion, and enabling it to regulate and utilize its emotions [3]. This places emphases on enriched interaction patterns between humans and robots, by providing a prospect for assistance, companionship, and even therapy for those experiencing physical or mental distress [5]. However, this debate is usually lost when discussing the nonverbal interaction of robotic arms and the expression of emotions and computational empathy. [8] argued that nonverbal information (motion, posture, gestures) is vital for social interaction. This is its communicative interface to the user, which serves likeability, increases user satisfaction, and perceived as trustworthy [4]. By exploring how emotion and motion interact, we could come up with strategies for understanding non-verbal expressions of emotional empathy. Furthermore, we could even explore users' expectation regarding a robot that expresses its emotions through motion, therefore understand whether motion and emotion correlate. For that reason, the main objective of this study was to read information from motion and emotional empathy, as well as users' expectations regarding the interaction.

II. Motion in [E]motion: Move Physically and the Power to Move Emotionally

The relationship between motion (bodily movement) and emotion (feelings) may not be considered an etymological coincidence by some scholars. Most of us may not even have thought about this, but the roots for motion and emotion are virtually identical. The English word emotion comes from the Latin word *Movere* meaning to move and *exmovere* or *emovere* meaning to move out, hence to excite [10]. This derivation suggests a close link between emotion and body movements [10]. Ultimately, meaning there is a close relationship between the two variables, emotion and motion.

Current robots, whether humanoids or robotic arms are being designed to function as industrial aids, as well as for as 'social partners' [7] and companions. Therefore, as much as their physical embodiment is considered to be important; their emotional embodiment should also be believed to be the same value. Robots as social agents and allies should be able to embody emotionally empathetic states when interacting with humans, no matter their physical embodiment. For example, a robotic arm (KUKA), companions (AIST's PARO), household pets (Sony's AIBO), domestic cleaners (iRobot's Roomba), healthcare assistants (RIKEN Japan's Ri-Man), and educational aids (MIT's Kismet and Leo). Design of such robots depends on the interaction and social skills. In situations such as robotic arms, non-verbal emotional states of the robot have to be embodied, personified or exemplified by exploiting motion as robot body language. This can be in conjunction with the voice and screen semantic of the robot (if any), without excluding the tempo, pitch and pattern of interaction. For instance, what we refer to as '*emotion-motion interface'* (EMI), therefore, exploring the emotion-motion interaction on the robot.

A theory on body expressions called the Laban Movement Analysis (LMA; Laban, 1980) assumes two opposing forms of body movement: fighting form (active, prominent, brisk movements) and indulging form (unsteady weak movements), which reveal subjective inner attitudes or states [10]. This theory helps us understand how movement or motion expresses internal states. In one study, "change in the robot's motor behavior to match the user's speed invoked an *empathetic Chameleon Effect response* and improved the participants' overall perception of the robot" [2]. It is also argued that body movements' information provides sufficient guidance for people to perceive the expression of emotion [7]. In another study that explored the meaning awarded to motion characteristics (for example speed); it was revealed that perception of emotion such as fast, jerky movements were linked with anger and happiness, while slow, smooth movements were associated with sadness [7].

Motions with strong velocity or speed tend to be perceived as anger or happiness, while motions with weak velocity tend to be perceived as sadness or tired [10]. Which means that fast speed or velocity does not necessarily mean optimistic emotional experiences (e.g. happiness) and slow speed or velocity does not always mean pessimistic emotional experiences (e.g. sadness). Though, [7] argued that differences in the kinematics of arm movements have helped differentiate between anger, joy, and sadness. However, we can still argue

*This work has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 721619 for the SOCRATES project.

Naomi Yvonne Mbelekani, Ben-Gurion University of the Negev, Beersheba 84105, Israel; work e-mail: mbelekan@post.bgu.ac.il (ynmbelekani@gmail.com).

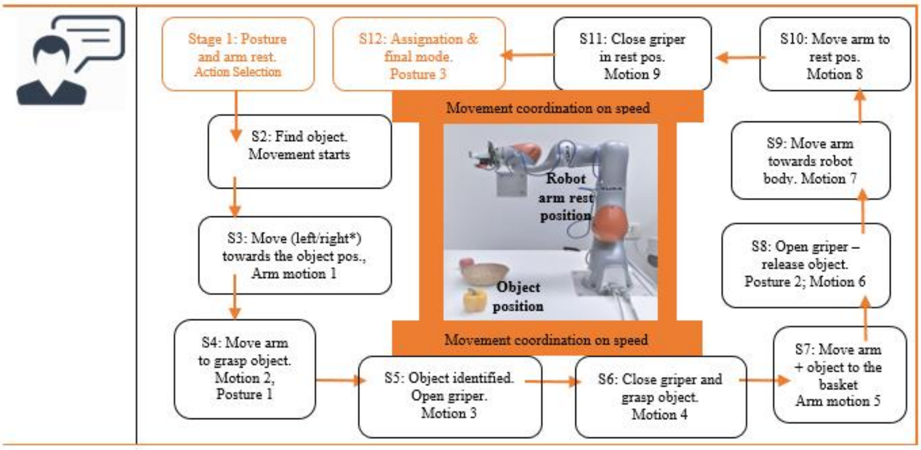

Fig 1. Techno-Scenario: proposed state automaton design for the use case starting from an arm rest position. (*the commands for the robot were either move arm right, left, forward, back, up or down towards the object, and close or open griper)

that emotions have a tendency to be affected by body motion, for example, people can be emotionally engaged when watching dance routines [7]. Ultimately, it is important to understand the interface, the transition through it, and the meaning it holds for interaction moving forward.

A. *Gesture and posture in emotion communication*

Humans use imitation of gestures and postures as tools of communication, and it is regarded as important in enhancing the quality of interaction in HRI [2]. Thus, imitation triggers some social interactions [3]. In one study where participants were asked to use a Nintendo Wii remote to mime gestures simultaneously with a robot, they noted feeling more comfortable while completing the task when the robot synchronized/mirrored their gesture speed [2]. Understanding how users perceive and give meaning to robot postures and gestures supports the design of robots that are able to socially and emotionally interact. Gestures have been identified as crucial to the design of robots [7]. Furthermore, robotic arms' body language (through gestures or postures) should be explored as a medium of conveying robot intentions [4]. We can hence argue that studies on robot postures and gestures are important because of the following reasons borrowed from [7]:

1) studying gesture interpretation is necessary to improve HRI especially for robots that have limited ability for vocal and facial expressivity;

2) previous studies in HRI have focused on how gestures are created without evaluating users' understanding of those gestures, so little is known about what factors affect gesture perception;

3) no previous work has investigated the characteristics of good designers and the role of expertise in gesture authorship.

This study explores non-verbal cues of dialogue and social behavior on a robot's bodily gesture and posture (approachable versus less approachable) and their subjective meanings. People tend to rely on facial expression as a key indicator [7], hence it is important to examine whether, in the absence of a face, robots can still convey emotional interaction using postures and gestures. Based on the study aim, the following question was explored: Can a robotic arm be considered as expressing emotion (empathy) based on degrees of motion response, gesture and posture? The following hypotheses were tested to address this question:

H1: the robot's gesticulation motion mirrors emotional empathy based on its interactive speed.

H2: the robot's postures are an exhibition of subjective meanings.

III. Study Methods

The study aimed to examine a robot's non-verbal expression of emotionally empathetic interaction through motion in a table setting scenario.

A. *Participants*

Four female individuals (age range: 19 to 27, M=20) were recruited randomly, whose native language consists of Arabic, English, Malayalam, and Russian. The highest education achieved were high school, bachelor, and masters. The study was conducted in a lab room (Intelligent robotics lab) at the Ben-Gurion University of the Negev, Israel.

B. *Apparatus*

The robot KUKA LBR IIWA was used in this study, which comprises an interactive interface: one hand with multiple joints, seven actuated Degrees of Freedom (DOF) and a refined control system.

C. *Design*

The study was a within-subject experiment design. The independent variable tested was the speed of the robot, two levels: fast (100% full speed) and slow (50 % speed). The dependent variable tested was an emotionally empathetic expression. The study measured subjectivity by questionnaires. Descriptive analysis of the study results was conducted afterwards.

D. *Procedure*

(a) Using Wizard of Oz, the scenario involved asking the participant to give voice commands to the robot in the form of direction (e.g. left-right, up-down, back-forward) on picking objects and placing them in a basket (see Fig 1.). They experienced two different motions: slow and fast mode. The robot KUKA was operated to adopt and personify a slow-motion profile in contrast to fast motion. After the interaction, the participants were instructed to answer questions related to the interaction, e.g. "Pretend that you are in the scenario and you are feeling sad/happy, then describe how you would experience the interaction with the robot."

The predominant framework model in this study is, in essence, a model in which motion and emotion interact which in turn predispose or motivate the robot towards explicit behaviors. For empathy is a contested concept and emotion is a broad phenomenon, the following are used as frameworks of understanding emotionally empathetic interaction in this study: compassion, friendly, understanding, intentional, relatable, considerate, and trustworthy. While interfering and annoying are used as negative emotional experiences.

(b) As the study was divided into two parts, the second part involved asking the participants to describe the meaning of the robot posture, e.g., “what message do you think is the robot conveying to you?”. They were provided with six postures, and to avoid bias by giving them a selection of emotions and them merely picking out what they think the researcher preferred, we asked them to think about it and give their own thought processed meanings. This required them to actually analyze the posture and give meaning based on their own understanding. This study used an image display methodology to acquire understanding.

Participants also filled out demographic information, the Technology Adoption Propensity questionnaire (TAP) [13], and the Negative Attitudes toward Robots Scale (NARS) survey [15]. This study attempts to design interaction using non-verbal programmable emotionally empathetic traits.

E. *Measure*

In the first part (a) of the study, we considered the subjective reality, thus how many times participants ticked an answer, which we then calculated to check for predilections. We then used descriptive analysis to understand the results achieved. In the second part (b) of the study, we paid attention to the distribution of subjective meaning on a robot’s postures, based on participants’ understanding.

IV. Preliminary Results and Discussion

The results achieved from the preliminary study revealed the following notions. Based on the TAP, on a scale from 1-strongly disagrees to 5-strongly agree; 2 participants scored 4-agree and 2 participants scored 5-strongly agree towards the question: “technology gives me more control over my daily life”. This revealed positive attitudes towards technology as participants thought it gives them a sense of control in their everyday lives. These results show confidence and a positive attitude towards the use of new technological devices. With regards to the NARS, on a scale from 1-strongly disagrees to 5-strongly agree; 3 participants scored 5-strongly disagree and one participant scored 1-strongly agreed on the question “I would feel uneasy if robots really had emotions.” This revealed positive attitudes towards robots that display emotions and that they did not have negative thoughts about robots expressing emotions.

A. *Effects of motion and emotion valence*

Work on expressive robots for emotional interaction with humans is receiving increasing attention. Robots can engage in social interaction through socio-emotional intelligence [1], which enables the robot in sensing and interpreting various human emotions, moods and attitudes to guide its interaction. The processes used as frameworks for understanding emotion and empathy interaction in HRI are:

For the slow mode: The results on their experience interacting with the robot revealed that the interaction was perceived as understandable and friendly. When asked if you were feeling sad, how would you consider the robot’s motion, as a result, concepts such as considerate, friendly and relatable separately received a less score; while trustworthy received a moderate score, and understandable was highly scored; whereas annoying received the least score. This tells us that slow motion has emotional significance, and may be considered in instances where a user may be feeling sad. In the scenario where the user may be feeling happy, a majority of the participants opted for friendly and trustworthy; while a small number scored considerate, understanding, and relatable. The results on the slow motion and its relation to emotional experience revealed a positive attitude and emotional experience.

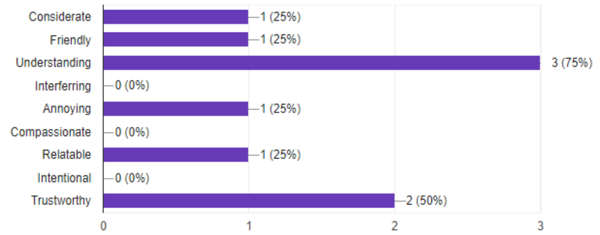

Fig. 2: Slow mode: Feeling sad and the robot’s motion:

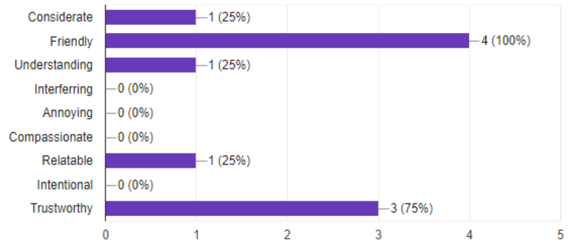

Fig. 3: Slow mode: Feeling happy and the robot’s motion:

For the fast mode: The results, in this case, revealed that a majority of the participants chose positive experiences while interacting with the robot. With regards to them feeling sad while interacting with the robot, a majority of the participants considered the robot’s motion as considerate and friendly, while understandable, relatable and trustworthy received an average score; and the least score being interfering and annoying. In cases where the participants may be feeling happy, results revealed high scores for the robot as considerate, friendly and trustworthy; with the robot as understandable, compassionate and relatable receiving an average score; while interfering received the least score. Similar to the slow-motion mode, the results show a positive emotional experience towards both motion modes of the robot.

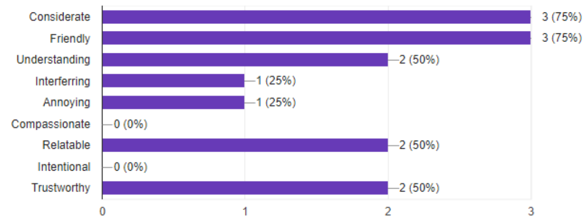

Fig. 4: Fast mode: Feeling sad and the robot’s motion

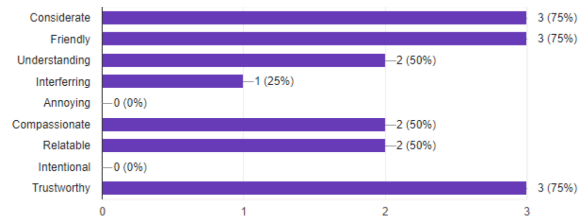

Fig. 5: Fast mode: Feeling happy and the robot’s motion

As a result, what we see from these results is that people's emotional understanding and experience through motion is varied and subjective. Due to the size of the sample, no clear predictions were made. However, whether fast or slow depending on individual differences, it is accurate to state that motion and emotion interact. Based on the idea that this study's sample size was small, as it is a preparatory study, the current results cannot be generalized to a wider population. Although, we expect to achieve a more generalizable result based on a larger sample size on our forthcoming study, which will be extended to older adults.

B. Situational context on expressed user expectations

When asked about their expectation regarding non-verbal emotion, the majority of the participants stated that they would like for motion of the robot to show emotional empathy, with one preferred a verbal interaction. The following results show when users would like for the robot to express emotional empathy, see Fig 6:

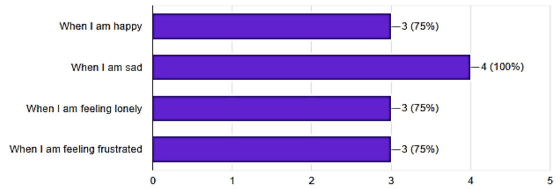

Fig. 6: Expressed user expectation.

C. Posture characteristics and expressed meaning

With regards to robot gesture and posture, descriptions were given on the robot's posture (see Fig 7).

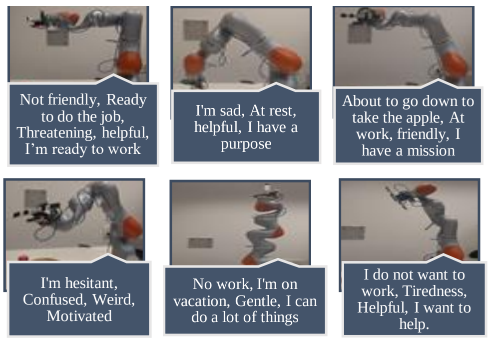

Fig. 7: Expressed meaning on robot posture

Participants had different meanings on the different postures. This shows that robot postures and the meaning they convey are subjective. What one sees as friendly, another may see it as not friendly. As a result, we can argue that meaning is subjective and a response to emotion.

V. Conclusion

The study contributes to the field of emotion (empathy) expression and user expectations in HRI. This aims to look at certain properties of the robot, such as motion and emotion interaction. This study is important because adding emotion to motion or creating natural emotionally meaningful movement is one of the next and anticipated phases of robotics, thus proving valuable for robots. However, due to the small sample size, the results cannot be generalized to a larger population but can be seen as a starting point. Furthermore, no clear correlation between motion and emotion was observed. Thus, whether one had an effect on the other cannot be claimed without further results.

Acknowledgement

We acknowledge the assistance provided by the participants and reviewers involved in making this study a success, as well as the funding provided by SOCRATES, an MSCA-ITN-2016 - Innovative Training Networks funded by EC under grant agreement No 721619.

References

[1] Breazeal, C. (2003). Emotion and sociable humanoid robots. 59: 119-155. DOI:10.1016/S1071-5819(03)00018-1

[2] Burns, R., Jeon, M., & Hyuk Park, C. (2018). Robotic Motion Learning Framework to Promote Social Engagement. *Applied Science*, *8*: 241. DOI:10.3390/app8020241

[3] Cañamero, L., & Gaussier, P. (2004). Emotion understanding: Robots as tools and models. DOI:10.1093/acprof:oso/9780198528845.003.0009

[4] Chatterjee, S., Shriki, O., Shalev, I., & Oron Gilad, T. (2016, August 26-31). Postures of a Robot Arm- window to robot intentions? 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN). Columbia University, NY, USA

[5] Goodrich, M. A., & Schultz, A. C. (2007). Human-Robot Interaction: A survey. 1(3): 203-275. DOI:10.1561/1100000005

[6] Ioannidou, F., & Konstantikaki, V. (2008). Empathy and emotional intelligence: What is it really about? *International Journal of Caring Sciences*, *1*(3):118-123. http://www.emotionalliteracyfoundation.org/research/Vol1_Issue3_03_Ioannidou.pdf

[7] Klein, B., Gaedt, L., & Cook, G. (2013). Emotional robots. GeroPsych: The Journal of Gerontopsychology and Geriatric Psychiatry, 26(2): 89-99. DOI:10.1024/1662-9647/a000085

[8] Li, J., & Chignell, M. (2011). Communication of emotion in social robots through simple head and arm movements. *International Journal of Social Robot*, *3*: 125-142. DOI 10.1007/s12369-010-0071-x

[9] Masuda, M., Kato, S., & Itoh, H. (2009). Emotion detection from body motion of human form robot based on Laban Movement Analysis. *PRIMA*, *LNAI* *5925*: 322-334. https://link.springer.com/content/pdf/10.1007%2F978-3-642-11161-7_22.pdf

[10] Mccoll, D., & Nejat, G. (2013). Meal - time with a socially assistive robot and older adults at a long-term care facility, 2(1): 152-171. DOI:10.5898/JHRI.2.1.McColl

[11] Morita, J., Nagai, Y., & Moritsu, T. (2013). Relations between body motion and emotion: Analysis based on Laban Movement Analysis. https://mindmodeling.org/cogsci2013/papers/0202/paper0202.pdf

[12] Truschzinski, M., & Müller, N.H. (2014). An emotional model for social robots. ACM/IEEE international conference on human-robot interaction '14, Bielefeld, Germany.

[13] Ratchford, M, and Barnhart, M. (2012). Development and validation of the technology adoption propensity (TAP) index. *Journal of Business Research*, *65*: 1209–1215. DOI:10.1016/j.jbusres.2011.07.001

[14] Smarr, C. A., Mitzner, T. L., Beer, J. M., Prakash, A., Chen, T. L., Kemp, C. C., & Rogers, W. A. (2014). Domestic robots for older adults: attitudes, preferences, and potential. *International Journal of Social Robotics*, *6*(2): 229-247. DOI: 10.1007/s12369-013-0220-0

[15] Syrdal, D. S., Dautenhahn, K., Koay, K. L., & Walters, M. L. (2009). The Negative Attitudes Towards Robots Scale and reactions to robot behaviour in a live Human-Robot Interaction study. in Adaptive and Emergent Behaviour and Complex Systems: Procs of the 23rd Convention of the Society for the Study of Artificial Intelligence and Simulation of Behaviour, AISB 2009. SSAISB, pp. 109-115. URI: http://hdl.handle.net/2299/9641

[16] Yang-McCourt, I., & Bahli, B. (2014). Motion and emotion: An integrative approach of cognition and emotion in IS usage. *XXII Conférence Internationale de Management Stratégique*.