

**Affective Computing**  
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**Indraprastha Institute of Information Technology, Delhi**

**Week - 10**  
**Lecture - 34**  
**Tutorial Research Paper Discussion**

Good morning everyone. I am Ashwini. I am a PhD scholar under Dr. Jainendra Shukla at Human Machine Interaction Lab, IIIT Delhi.

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INFORMATION TECHNOLOGY DELHI



**An Autonomous Cognitive Empathy Model  
Responsive to User's Facial Emotion Expressions**

Authors: ELAHE BAGHERI, PABLO G. ESTEBAN, HOANG-LONG CAO, ALBERT DE BEIR, DIRK LEFEBER, and BRAM  
VANDERBORCHT,


*Robotics and Multibody Mechanics Research Group, Vrije Universiteit Brussel and Flanders Make*  
Presented by: Ashwini B, Human-Machine Interaction Lab, IIITD



Today I will be discussing the paper on An Autonomous Cognitive Empathy Model Responsive to User's Facial Motion Expressions by Bagheri et al.

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**Motivation** 

- Effectiveness of user-robot interactions affects successful social robot services
- Robot interactions:
  - Smooth
  - Engaged
  - Humanoid
- Cognitive concepts focused for effective Human-Robot interactions
  - Trust [14],
  - Personality effect [32],
  - Empathy [70]



Like in any interactions, whether it be human-human interaction or human-machine interaction, the effectiveness of the interaction depends upon how well the partners of interaction understand the intense and emotions of each other and respond appropriately. In a social robotics environment, the effectiveness of the interaction depends upon how the robot responds emotionally and empathetically towards the users or the target. To make this possible, the interaction has to be smooth, engaged, natural and human-like.

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A slide titled "Empathy" with a blue header bar. The slide content is as follows:

- Definitions
  - a set of constructs that connects the responses of one individual to the experiences of another [Davis, 2006]
  - the capacity to react emotionally, when perceiving another person experiencing or about to experience an emotion [Wispe, 1987]
  - an affective response more appropriate to other's situation than to one's own [Hoffman, 2001]
- Two kinds of Empathy
  - Cognitive
  - Affective
- Affective Factors on Empathy
  - Intrinsic features of the shared emotion
  - Characteristics of the empathizer
  - Relationship between empathizer and target
  - Situational context
- Empathic Behavior Level

In the bottom right corner of the slide, there is a small video inset showing a woman with dark hair, wearing a yellow top, speaking.

There are several studies that are worked on in this direction. Before going into the details of this paper, let us understand what is empathy, what are the factors that affect the empathetic responses, what are the different kinds of empathy and levels of empathy. Literature has defined empathy in different way.

For this study, the authors have adopted the definition in such a way that the empathy is defined as the responses of the empathizer towards the emotions of the target, which aligns with the definition given by Hoffman et al. There have been two kinds of empathy. One is the cognitive empathy and the second one is affective empathy.

In cognitive empathy, the empathizer perceives the emotions of the target in a rational or logical manner while in affective empathy, the empathizer considers or perceives the

emotions of the target more emotionally or a natural way. This could be considered as an intrinsic empathy.

There are different factors that affect the emotional response, which also involves empathetic response. First one is the intrinsic features of the shared emotions. This is in some way representing the nature of the target's emotions. What is the emotion expressed by the target or the user, whether it is positive or negative, whether it is strong emotion or a certain emotion, what is the salience of the emotions expressed by the target.

Second one is the characteristics of the empathizer. This basically represents the personality of the empathizer, whether the empathizer is extrovert or introvert, the gender of the empathizer, the age of the empathizer, the mood of the empathizer, etcetera affects the emotional response.

Third one is the relationship between the empathizer and target. How well you understand the target depends upon what is the relationship that you have with the target or the user. You may not respond in the same way to a stranger as that of a friend. Third one is the situational context. It depends upon when and where and how you respond to the user's emotion.

The empathetic behaviors has been categorized into two levels, one is parallel empathy and reactive empathy. In parallel empathy, you mimic the emotions of the target or the user. That means if the user is sad, you respond in a way that aligns with the emotions of the user. In reactive empathy, you feel and empathize with the user in such a way that the user's distress is reduced. You uplift the positive emotions in the user while reducing the negative emotional energy in the user.

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**State of the Art** IITD

- Major focus on parallel empathy
- Relation between target and empathizer
- Characteristics of empathizer
  - Personality
  - Mood
  - Gender
  - Age
- Humor and empathy
- Reactive empathy:
  - Eg:- Predefined verbal comments
- Empathy Model
  - Companion Assisted Reactive Empathizer (CARE)



The existing literature has studied different kinds of empathy, parallel as well as reactive. Most of the works have focused on parallel empathy, where the emotions of the user is identified and the empathizer also aligns with the emotions of the user. Even though the reactive empathy has been studied, it has been limited to generating responses in the form of verbal comments.

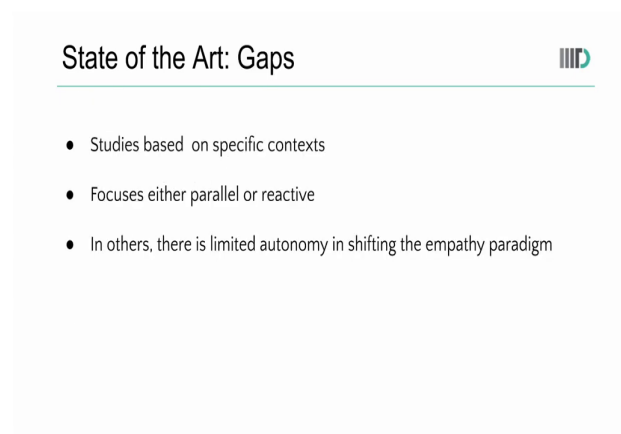

Machine learning techniques have been extensively used for developing models for empathizing, developing; machine learning models have been extensively tried for developing emotional empathetic model. One of those is companion assisted reactive empathizer.

In this, the empathizer is developed in a virtual environment with human trainers. The human trainers interact with each other during a virtual interaction platform. During these

interactions, they exhibit emotions and these emotions are understood and perceived by each one of these partners and they react appropriately to the emotions of the partner.

This has been used for training which also involves the physiological signals like heart rate, PPG etcetera from the interactive partners, and which is used to understand the emotions of the interacting partners, and used to generate a response in return to it. One of the drawbacks of this study is that we have to understand the different context, the different set of possibilities for these interactions to happen in order to predict the appropriate responses for each interaction in sessions.

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The slide is titled "State of the Art: Gaps" and features a bulleted list of three points. The text on the slide is as follows:

- Studies based on specific contexts
- Focuses either parallel or reactive
- In others, there is limited autonomy in shifting the empathy paradigm

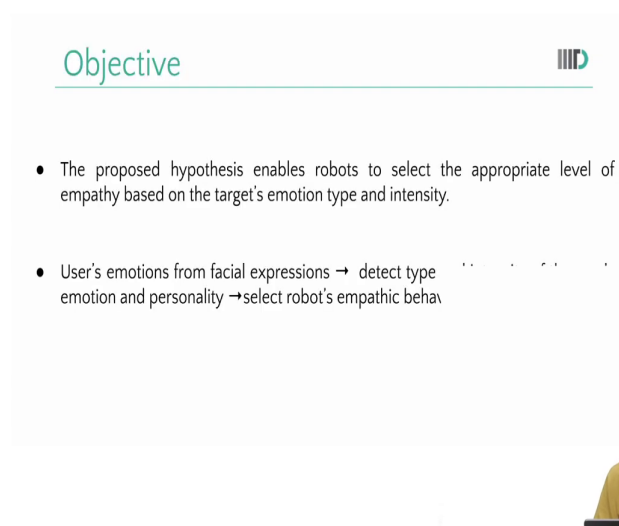



By looking into the literature, we could understand that there are many gaps like most of these studies are specific to a particular context. They have considered only a specific kind of

empathy model for example, either the parallel empathy or the reactive empathy or these studies lack autonomous decisions by the empathizer.

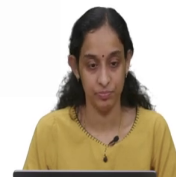
Whether to generate a reactive response or a parallel response has to be decided by the empathizer in real time scenarios. These studies could not make the empathizer empowered enough to make that decisions.

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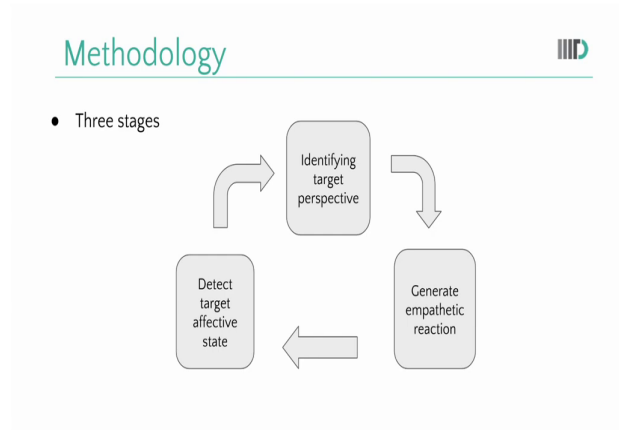
**Objective**

- The proposed hypothesis enables robots to select the appropriate level of empathy based on the target's emotion type and intensity.
- User's emotions from facial expressions → detect type of emotion and personality → select robot's empathic behavior



In this study, the authors have tried to generate a autonomous empathizer which understands or perceives the emotions of the target and generates appropriate reactive or parallel responses in response to the user's emotions. To understand or perceive the emotions of the target, here the authors have relied upon facial expressions. Facial expressions are one of the major components which aids the expression of emotions.

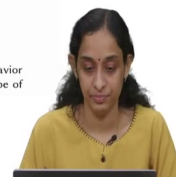
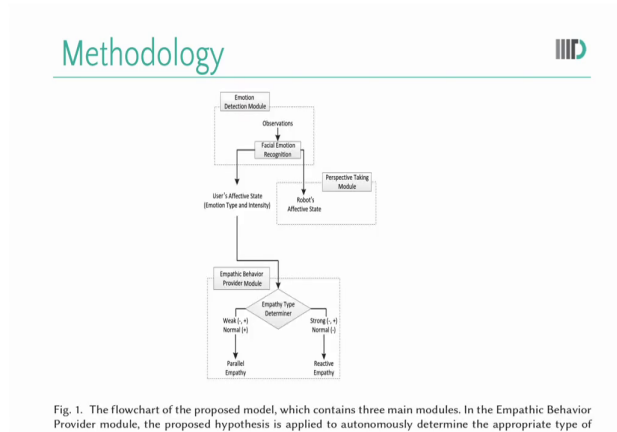
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Coming onto the methodology, there are 3 stages in this process. First is to detect the target's affective state. Once that is detected, we have to understand what is the target's perspective of the emotion. Once that is understood by the empathizer, the empathizer has to generate an empathetic response to that emotion. And this process goes on until the interaction ends.



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This work has 3 different modules. One is the emotion detection module, where the emotions felt by the target is perceived using facial expressions of the target. Now, the emotions of the target is perceived using this detected module. And finally, based on the detected emotions, the empathizer generates responses, empathetic responses to be specific, based on the emotions and the intensity of the emotions expressed by the user.

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## Methodology: Emotion detection module

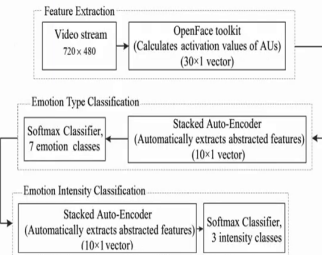
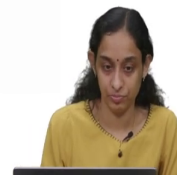


Fig. 4. The overall schematic of the facial emotion detection module is threefold: first, the live video of a user is sent to OpenFace to detect the activation values of considered AUs; second, the proposed SAE will classify the input data into one of the seven considered emotions to detect the type of emotion. Finally, the other SAE will classify the activation values of AUs into one of the three possible classes to detect the intensity of




The first module or the first step in this process is to understand the emotions of the user. How will you understand the emotions? As I said, one of the major factors that helps us to express our emotion is our face or the facial expressions. To define the emotions using facial expressions, Ekman has defined an emotional model which has 6 basic emotions; happy, sad, fear, anger, surprise and disgust.


His emotional model is a categorical one and for the purpose of his study, the authors has used Ekman's emotional models. And Ekman has also defined that all these emotions could be expressed using different facial muscles which are called the facial action units. There are 55 facial action units which could express different emotions by activating or by relaxation or contraction of these facial muscles.

From the video stream using open phase toolkit, these facial action units are extracted which is sent to a stacked auto-encoder model and finally, classified into the different emotions using a Softmax Classifier. Again, once the emotions are identified, we have to understand the intensity of emotion to generate appropriate empathetic responses, which is again performed using a machine learning model consisting of a stacked auto-encoder and a Softmax Classifier.

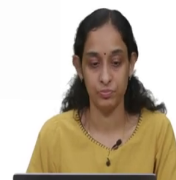
I am not going into the details of the architecture; you can find it in the paper.

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Methodology: Perspective Taking Module 


- By taking the target's perspective, the empathizer is able to feel how the target is feeling.
- Affective state of empathizer → emotion detected from



Once we detect the emotions using the facial action units, next is to understand the perceptions, emotional perceptions of the target. For representing the emotional perception of

the target, we assign the detected emotion to the target. And this is considered as the emotions expressed by the user with whom the empathizer is interacting.

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### Methodology: Empathic Behavior Provider Module

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- Strong emotion → reactive empathy
- Weak emotions → parallel empathy

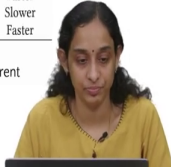
Emotion Category	Emotion Type	Emotion Intensity		
		Weak	Normal	Strong
Positive	Happiness	Parallel	Parallel	Reactive
	Surprise	Parallel	Parallel	Reactive
Negative	Anger	Parallel	Reactive	Reactive
	Fear	Parallel	Reactive	Reactive
	Sadness	Parallel	Reactive	Reactive
	Disgust	Parallel	Reactive	Reactive

Emotion	Volume [57]	Rate [57]	Stiffness [18]
<b>Happiness</b>	Higher	Faster or slower	Faster
<b>Sadness</b>	Lower	Slightly slower	Slower
<b>Fear</b>	Normal	Much faster	Slower
<b>Anger</b>	Higher	Slightly faster	Faster
<b>Disgust</b>	Lower	Very much slower	Slower
<b>Surprise</b>	Higher	Faster	Faster

Table 1: Proposed Empathic Level for Different Emotion Categories and Intensity

Table 2: The Influence of Emotions on Different Parameters

Stiffness refers to body motion speed.



The last step in this procedure is to generate the empathetic behavior by the empathizer. The authors have defined both reactive empathy as well as parallel empathy depending upon the intensity of the intensity of the emotions expressed by the user. For subtle emotions or positive emotions, parallel empathy is used and for strong emotions or negative emotions, reactive empathy is performed.

You can see the different emotional responses and the combinations used in these tables. For example, if the emotion is happiness and the intensity is high, then the emotional response is parallel. For example, if the emotion category is positive and the emotion type is happiness or

surprise, the based on the emotional intensity, whether it is weak or normal, the responses also vary.


Now, how should we generate the empathetic response? What are the changes that has to be made in the response behavior of the empathizer? You know, the emotions could be expressed or humans express their emotions in different ways. There will be some changes in their facial expressions.

The gestures that make also represent the emotional intense of the person, also the pitch and the tone of the voice they generate or the intonation of the pronunciation, intonation or the pronunciation or intonation of the emotional state. Considering that, in this study, the emotional empathetic response of the empathizer is defined using various parameters.

One is the stiffness of the body activities or stiffness of the joints of the interactive agent or the empathizer. Second is the pitch and intensity of the voice of the robot or the empathizer and also the eye color of the empathizer. These things are used to respond with parallel empathy. And if the empathizer is adopting a reactive empathy, then the eye color as well as verbal comments were used.

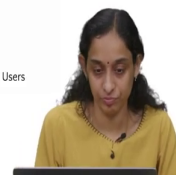
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Methodology: Empathic Behavior Provider Module 

Emotion type	Extrovert		Introvert	
	Parallel empathy	Reactive empathy	Parallel empathy	Reactive empathy
Happiness	Well done. Cool! Nice!	I'm happy that you're happy. You seem more beautiful, when you laugh.	Great! Cool! Nice!	I am happy that you are happy. You seem more beautiful, when you are laughing.
Sadness	I can understand. Ooh, I feel sad too!	Hey, everything would be fine again, don't worry. I understand your feeling, hope everything would be better.	I can understand. I feel sad too!	Everything would be fine again. I understand how you feel, I've been through a similar situation.
Fear	It seems a bit fearful!	Don't be afraid, You're not alone. Come on, I do believe in you.	It seems a bit fearful! I still believe in you!	I am sure you are braver than this.
Anger	Calm down, please! Let it go.	Take some breaths and let it go. Something isn't quite right, but it will get better for sure.	Please calm down! Let it go.	Take some breaths and let it go. Something is not quite right, but it will get better for sure.
Surprise	Wow! It's a real surprise. This shocked me too.	I can't believe it. Fantastic it's really great! I really surprised me.	Wow! It is a real surprise! This just shocked me.	I can not believe it. Fantastic it is really great.
Disgust	Oohh bad. No favor in it. I don't like it.	Might be better than what you think. It's not too bad, maybe you can try.	It is not my favorite. I have no favor in it. I do not like it neither.	It is not too bad, you can try once. Might be better than what you think.

Table 3: The List of Applied Empathic Utterances, which in Reactive Empathy Are Longer Than Parallel Empathy and for Extrovert Users  
*Arav Indraprastha*



The empathetic behavior provider module: This, the empathetic behavior also defines the personality of the empathizer, whether the empathizer should create a introvert behavior or a extrovert behavior. This depends upon the similarity attraction principle used in psychology. Usually, people respond positively or people find it more interesting to interact with people who are similar to their traits.

So, depending upon the personality of the target, the empathizer's behavior is also changed, and accordingly the speech, the eye color, the behavior, gestures, etcetera are also changed.

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### Results: Emotion detection module

- Facial emotion detection module
  - Ryerson Audio-Visual Database of Emotional Speech and Song (RAVDESS)

Fig 3 Performance on train and test data using five-fold cross-validation.

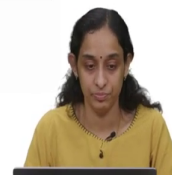
Table 4: Performance on Each Emotion Classification Rate and False Alarm Rate on Train Data

Class	Neutral	Happiness	Sadness	Fear	Anger	Surprise	Disgust	Ave.
CR(%)	98.5	<b>99.5</b>	92.5	90.3	98.1	98.4	98.4	96.5
FAR(%)	1.45	0.45	0.57	0.31	<b>0.30</b>	0.34	0.58	0.57

Table 5: Performance on Each Emotion Classification


	Happiness			Sadness			Fear			Anger			Disgust			Surprise		
	W	N	S	W	N	S	W	N	S	W	N	S	W	N	S	W	N	S
CR(%)	88.3	91.3	86.4	92.5	88.2	91.1	90.2	92.1	91.9	89.3	92.3	91.1	93.5	87.4	95.3	93.9	89.1	92.7
FAR(%)	3.3	4.9	4.0	5.3	4.7	4.9	4.6	5.2	3.5	3.8	5.7	4.7	5.9	2.9	3.6	2.5	5.3	5.8

W, N, and S refer to Weak, Normal, and Strong Emotion Intensity Levels.



Coming on to the results. The facial emotion recognition module is trained on RAVDESS dataset, which is a popular dataset used for emotion detection.

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### Results: Empathic Behavior Provider Module Verification

- Eliciting emotions: performances of America's Got Talent (AGT) show on Pepper's tablet → six basic emotions
- Two parts:
  - Part 1: Autonomous Cognitive Empathic Model (ACEM)
  - Part 2: Basic Empathic Model (BEM)


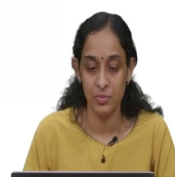


Fig 5. The setup of the experiment, where the user watched the considered videos on Pepper's tablet. (Authors obtained the



After which a user study is conducted to decide whether the autonomous empathetic, autonomous cognitive empathetic model is better than the existing models or not. In this a user scenario or a interactive scenario is defined, in which the participants or the target is shown videos in different emotional categories aligning to the Ekman's basic emotion model.

These videos were selected from America Got Talent Show, and during these interactions the different emotions are elicited in the users and a social robot, which is pepper robot in this case has been used to respond appropriately to the user's emotions. The study was conducted in two different parts.


One in which the empathizer or the social robot responds according to the autonomous cognitive empathetic model and in the second part the robot or the empathizer responds to a baseline model which is the basic empathetic model. The difference between the basic




empathetic model which is the baseline and the autonomous cognitive empathetic model is that, in basic empathetic model only the eye color and the verbal comment is produced by the empathizer.

While in ACEM or the autonomous cognitive empathetic model the empathizer changes the speech in donations, then the stiffness of the body, the eye color as well as generates the verbal comments depending upon the emotions and intensity of emotions of the user.

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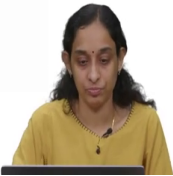


### Results: Empathic Behavior Provider Module Verification

- Measurement

Function	Definition	Assertions	ACEM		BEM	
			M	SD	M	SD
Intimacy	Sensitivity to other's needs and states.	Pepper knew when something was bothering me.	3.45	1.12	2.77	1.13
		Pepper knew when I was upset.	3.4	1.3	2.8	1.29
Emotional Security	Providing comfort and confidence.	If I was worried, Pepper would make me feel better.	3.15	1.23	2.57	1.22
		If I was nervous, Pepper would make me feel calmer.	2.97	1.23	2.45	1.16
		If I was upset, Pepper would make me feel better.	3.27	1.2	2.57	1.22
Social Presence	Perceived Message	My thoughts were clear to Pepper.	3.55	1.28	2.47	1.22
	Perceived Affective Interdependence (PAI).	Pepper's thoughts were clear to me.	3.57	1.3	3.05	1.32
		Pepper was influenced by my mood.	4.17	0.86	2.9	1.02
		I was influenced by Pepper's mood.	3.02	1.19	2.42	1.16

Table 6: Applied Functions of the Friendship Questionnaire with the Corresponding Mean and Standard Deviation



And after this the responses of the empathizer is evaluated on different parameters. One is the intimacy. Intimacy shows how sensible or how sensitive is the empathizer towards the target or the user. Second one is emotional security. This means how well the participant or the user feels confident and comfortable in interacting with the empathizer or the robotic agent here.

Third is social presence. In social presence the users evaluated the empathizer based on its sociability; how well they relate this robot or the empathizer as a social entity.

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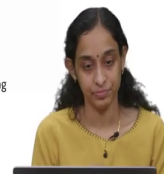


Results: Empathic Behavior Provider Module Verification

Measurement

Code/ Construct	Definition	Assertions	ACEM		BEM	
			M	SD	M	SD
Perceived Enjoyment (PENJ)	Feelings of joy/ pleasure associated with the use of the system.	I enjoy the robot talking to me.	3.77	1.27	3.17	1.14
		I enjoy doing things with the robot.	3.82	1.07	3.55	1.07
		I find the robot enjoyable.	3.92	1.06	3.15	1.04
		I find the robot fascinating.	3.9	0.83	3.17	0.99
Perceived Sociability (PS)	The perceived ability of the system to perform sociable behavior.	I find the robot boring.	2.1	1.11	2.5	1.26
		I consider the robot a pleasant conversational partner.	3.22	1.21	2.52	1.14
		I think the robot is nice.	4.27	0.8	3.67	1.12
		I find the robot pleasant to interact with.	3.67	0.93	2.92	0.98
Trust	The belief that the system performs with personal integrity and reliability.	I feel the robot understands me.	3.82	1.16	2.6	1.17
		I would trust the robot if it gave me advice.	2.6	1.3	2.02	1.01
Engagement	The process by which two partici- pants establish, maintain, and end their perceived connection.	I would follow the advice the robot gives me.	2.42	1.28	2.07	1.21
		It was fun playing with Pepper.	3.95	1.09	3.45	1.26
		Pepper made me participate more in the watching.	3.27	1.16	2.67	1.12
		Watching movie with Pepper caused me real feelings and emotions.	2.95	1.26	2.5	1.11
		I lost track of time while watching with Pepper.	3.32	1.27	2.92	1.23

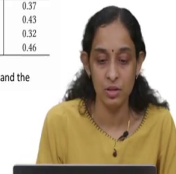
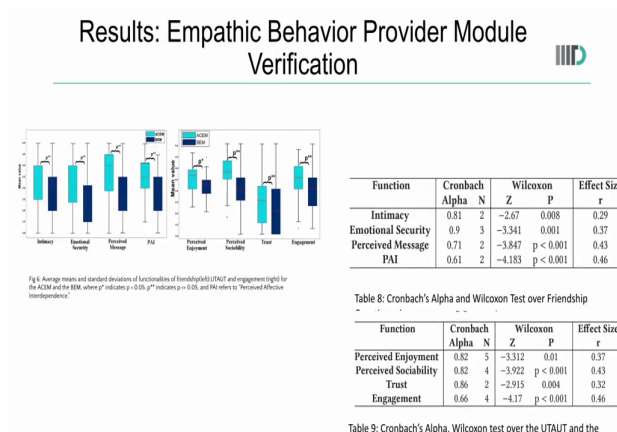
Table 7: The Applied Functions of the UTAUT Questionnaire and Engagement Assertions with the Corresponding



Next is perceived enjoyment which shows whether they whether the users enjoyed the interaction, what were their feeling about the interaction, whether it is positive or negative. And next is the perceived sociability. Again, this shows how this empathizer or the robotic agent could be used in a social interaction. Trust. Trust represents how well the empathizer could respond to the respond to the user reliably and what does the user understand about the integrity of the interactions.

Next is engagement. Engagement represents how well the interaction went, so that or how engaged the interaction were or how engaged the users were in the interaction so that the interaction can extend for a prolonged time.

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So, the robotic or the empathizer target interactions were evaluated based on these parameters. And the results are shown in these tables. It is evident from the figures that the autonomous cognitive empathetic model performed far better than the basic empathetic model in most of these parameters.

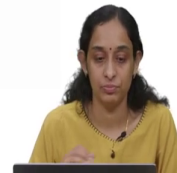
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**Contribution** 

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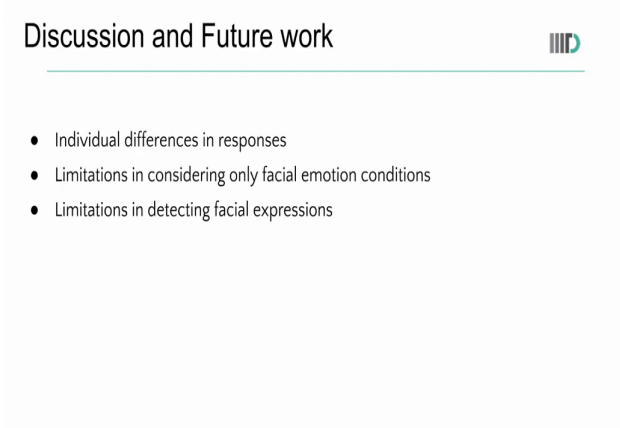

- Intimacy
- Emotional Security
- Social Presence
- Perceived Message Understanding
- Perceived Affective Interdependence
- Perceived Enjoyment
- Perceived Sociability
- Trust
- Engagement



Coming on to the contribution of this paper. This model has been seen to provide more effective interactions in terms of intimacy, emotional security of the target. They found the interactive agent or the empathizer as more social and considered it as a social entity good for social interactions. They found that their emotions were understood better by the empathizer. And it also showed that their empathetic, their emotional responses were dependent upon how well the empathizer responded to their emotions.


And according to the empathizer's responses, their moods or their emotions also varied. And they enjoyed these enjoyed these interactions, and they were more engaged and they had trust in these interactions or in these interactive agents.

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Discussion and Future work

- Individual differences in responses
- Limitations in considering only facial emotion conditions
- Limitations in detecting facial expressions


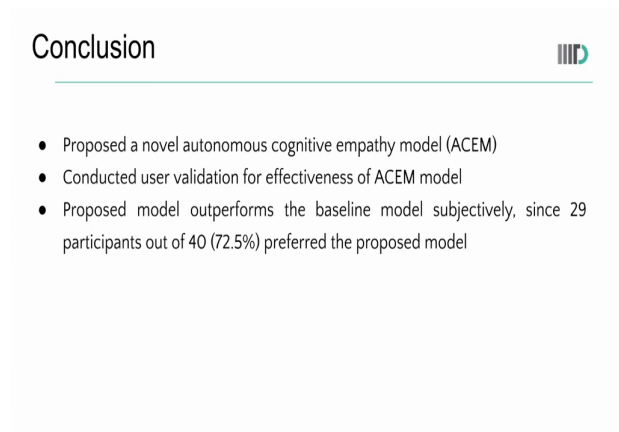


Coming on to some of the limitations of these studies, they having mixed responses on how well this, there have been there have been mixed emotions on the response behavior generated by the empathetic agent here. Some found that having more tactile responses like hugging or a touch on the shoulder might have made the interactions more better, must have made the interactions better.

And some thought that more expressions on the face of the empathizer or the Pepper robot might have been improved the interactions. Further, in this study only facial expressions were considered as an indication for emotions or intense of the user. Sometimes there may be other factors that can represents emotions better. Considering a holistic approach in the emotional perception will help in understanding the emotions of the target and react appropriately.

And this method, in general is restricted by the bottleneck of the performance of different facial expressions algorithms or facial expression detection algorithms.

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**Conclusion**

- Proposed a novel autonomous cognitive empathy model (ACEM)
- Conducted user validation for effectiveness of ACEM model
- Proposed model outperforms the baseline model subjectively, since 29 participants out of 40 (72.5%) preferred the proposed model



In short, this paper provides the in short, this paper studied a, in short, this paper explored an autonomous cognitive empathy model which could understand the emotional intense or moods of the user and generate a empathetic response system which is appropriate to the emotions of the user.

This study also conducted experiments to validate their claims, and the proposed method is found to be affective in making the interactions more engaged and affective using robots.

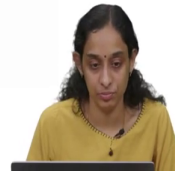
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## References



1. Elahe Bagheri, Pablo G. Esteban, Hoang-Long Cao, Albert De Beir, Dirk Lefeber, and Bram Vanderborght. 2020. An Autonomous Cognitive Empathy Model Responsive to Users' Facial Emotion Expressions. *ACM Trans. Interact. Intell. Syst.* 10, 3, Article 20 (November 2020), 23 pages. <https://doi.org/10.1145/3341198>



For more details, you can refer to Bagheri et al's paper.

Thank you.