Continual Learning for Affective Robotics
A Proof of Concept for Wellbeing

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* Equal Contribution
Affective Robots in Wellbeing Settings

(1) http://abovewhispers.com/2016/06/14/robot-receptionists-introduced-at-hospitals-in-belgium/
(2) https://www.clarehall.cam.ac.uk/news/robotswellbeing21/
(3) https://www.thetimes.co.uk/article/robot-carers-for-the-elderly-are-now-a-reality-in-japan-but-do-we-want-them-here-w8zpw0zd
Need for Personalised Interactions

Equipped with Learning Models
Interact and adapt.
Extend learning with other users.
Adapt to different user demographics.

(b) https://www.scmp.com/lifestyle/health-wellness/article/3024028/how-robot-nurses-could-help-care-worlds-elderly-and
Towards Continual Personalisation

Traditional Approaches

- Perceptron models trained on benchmark datasets enable generalisation across contexts and environments.
- Yet, generalisation comes at the cost of personalised learning.
- Costly to retrain and update models on-the-fly.

Personalisation towards Individual Expression

Robots that continually learn and adapt with each user.

- Adaptation with new data acquired during real-world interactions.
- Continual Learning of Individual Facial Expressions to embed continual personalisation in robots.

(b) https://marketingland.com/wp-content/ml-images/2016/03/emotions_is_1920.png
Continual Learning for Personalised Affect Perception

- Participant Image encoded into a latent variable ($z$).
- Image encodings and target labels (arousal-valence) used to generate additional images.
- *Imagined* images across a range of arousal-valence labels augment learning in a dual-memory self-organizing model.
- Episodic Memory learns *unique* representations of novel experiences.
- Semantic Memory learns compact *overlapping* representations that generalise across target labels.
• Pepper offering Positive Psychology (PP)-based wellbeing coaching.

• Interaction Script Developed with a Professional Psychologist.

• PP-based exercises or tasks:
  • Talk about two impactful things or events from the past two weeks.
  • Focus on gratitude and talk about two things to be grateful about.
  • Focus on two recent accomplishments and the strengths applied for those.

• Participant verbal responses (yes/no responses) and facial expressions observed to model personalised interactions.

• Adaptation achieved by modifying the interaction flow based on participant behaviour.
The Proposed Framework

Face Detected
Automatic Speech Recognition (ASR)
Utterance
"Yes, I feel very thankful!"
Speech Signal
Natural Language Generation (NLG)
2: "I'm happy to hear that, that sounds good."
NAOqi
Gesture Modelling
1: Welcome.
2: Question.
3: Wave Hands.
(a,v) prediction
Continual Learning for Aroual-Valence Prediction
I'm happy to hear that, that sounds good.
(0.2, 0.4)
Continual Learning for Aroual-Valence Prediction
Dialog Manager
Interaction Q1 Q2 Q3 Q4
1 | |
2 | |
3 | |
4 | |
5 | |
6 | |
7 | |
8 | |
Experiment Set-up

- 20 Participants (12 female, 5 male, 3 not disclosed).
  - Average Age: 26.70 ± 3.68 years from 12 different nationalities.
  - Screened using GAD7 and PHQ9 questionnaires to ensure non-clinical population.

- Between-subjects study design with random assignment to one of three experiment Conditions (Coach Variants):
  - **C1 – Static and Scripted**: Robot following the pre-defined script with no consideration towards participants affective responses.
  - **C2 – Affect-based Adaptation without Personalisation**: Off-the-shelf, state-of-the-art facial affect perception model used to determine participants’ affective responses. Robot responses adapted based on participants’ perceived affective state.
  - **C3 – Affect-based Adaptation with Continual Personalisation**: CLIFER-based personalised affect perception used to determine participants’ affective state. Robot responses adapted based on the robot’s perception.

Evaluation

• Evaluating participants’ **impressions** of Pepper as the Robotic Coach under the different conditions based on:

  • GODSPEED: Measuring *anthropomorphism, animacy, likeability, perceived intelligence* and *perceived safety*.
  
  • RoSAS: Measuring *warmth, competence* and *(dis) comfort*.
  
  • Customised Questions: Measuring whether participants felt the robot *understood what they said, how they felt and adapted* its behaviour accordingly.

• Mann-Whitney U Test to compare individual conditions.

* represents $p < 0.05$ and ** represents $p < 0.01$. 

Evaluation: GODSPEED
Evaluation: RoSAS


* represents p < 0.05 and ** represents p < 0.01.
Evaluation: Customised Questions

* represents $p < 0.05$ and ** represents $p < 0.01$. 
Key Outcomes

Conclusions

• First study investigating **continual learning** to improve robot’s perception of participant affective behaviour.

• **Proof-of-concept** evaluations highlight that **affective adaptation** is preferred over static, non-adaptive interactions.

• **Continual Personalisation** improves participant’s impressions for *anthropomorphism, animacy, likeability, warmth and comfort*.

• **Sensitivity** to individual differences in affective behaviour allows *empathetic* interactions, particularly beneficial for wellbeing scenarios.

Next Steps

• **Multi-modal analysis** of user behaviour to improve robot perception their affective state.

• Use of **Natural Language Understanding (NLU)** for *active listening*.

• Extending the experiments to **longitudinal** settings with *repeated interactions*.

• Extending the experiments with more participants across demographic distributions with respect to *gender* and *ethnicity*. 
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