Affectively Aligned Assistive Technology for Persons with Dementia[1]

Jyoti Joshi[2], Alexandra König[2], Zhengkun Shang[2], Julie M. Robillard[3], Linda E. Francis[4] and Jesse Hoey[2]

There are nearly 900 million people aged 60 years and over living worldwide, and this rise in life expectancy is associated with increased prevalence of age-associated diseases such as Alzheimer's Disease and Related Dementia (ADRD); today 46 million people live with dementia worldwide [1]. Dementia is characterized by the progressive deterioration of both cognitive and functional abilities, leading to a loss of the ability to perform Activities of Daily Living (ADLs) such as domestic activities and medication taking [2]. Assistive technologies have been proposed as a way to help people with dementia perform ADLs independently [3].

An assistive hand washing system, COACH, has previously been developed based on tracking hand locations and using pre-recorded "canned" verbal (audio) and visual (video) cues when the person stops making progress in the task [4]. When tested in a long-term care facility, it was found that in some cases it reduces the need for human assistance by 100% [3]. However, in some cases, the COACH failed to provide appropriate assistance, leading to confusion or agitation in the older adult end-user. This may be due to an affective (emotional) misalignment of the COACH with the specific needs or personality of the individual. While significant effort has been made to design prompts based on the methods and styles of human caregivers [5], a simple one-size-fits-all style of prompting may be limiting. For example, one person may find certain prompts to be too imperious, and would respond better to a more servile approach, while others may prefer a more imperative prompting style.

Many studies have found that identity changes dramatically over the course of dementia [6] and that persons with ADRD often have more vague or abstract notions of their self-identity [7] than do non-afflicted persons. Thus, explicit models of affective identity offer an attractive mechanism for developing more appropriate and effective assistive technologies. Our aim is therefore to develop *an emotionally Intelligent Cognitive Assistant (ICA) that takes into account the affective identity of the individual.*

The proposed ICA is based on the social-psychological principles of Affect Control Theory (ACT) [8]. ACT posits that interactions are guided by a psychological need to maximize the consistency between culturally shared *fundamental sentiments* about identities and behaviours, and the situationally created *transient impressions* about identities and behaviours in real-time interactions. Fundamental sentiments and transient impressions are interpretations of social objects, such as interactants' identities and behaviours, represented as vectors in a 3D affective space hypothesised to be a universal organising principle of human socio-emotional experience [9]. The basis vectors of the affective space correspond to feelings of Evaluation/valence, Potency/control, and Activity/arousal (EPA). Emotions in ACT have a clear definition. They are the vector differences between fundamental sentiments and transient impressions, and are used as signals of this difference to interaction partners in order to promote or restore alignment and consistency. A generalisation of ACT has been proposed, called *BayesACT*, that models uncertainty in identities, can learn about identities, and take actions that are simultaneously goal-directed and affect-sensitive [10], [11]. *BayesACT* is chosen for this application over more commonly used *appraisal* theories of emotion, as it explicitly models change and uncertainty in identity (a hallmark of Alzheimer's), and relies less exclusively on higher-level cognitive processes (e.g. goal and intention analysis), which are less well preserved in Alzheimer's.

Identities in ACT refer to situational roles that a person takes on when interacting with others. The associated sentiments are known as identity sentiments. Thus, in a professional context, when managing employees, a person may select an identity of "boss" with an associated sentiment that is slightly good (~ 0.5), quite powerful (~ 2.2), and somewhat active (~ 0.9) [1]. ACT also explains a person's overall sense of self as a synthesis or combination of many different identities that are regularly enacted [13]. This combination is referred to as the "*persona*", and the associated sentiment as the *fundamental self-sentiment* or *persona sentiment*. Thus, the "boss" may also be a "father", a "husband", and a "musician" for example. When moved to a long-term care facility, an older adult may have an identity of "patient" implied by their new institutional setting. The persona is a combination of these identities (with possibly different weights), and the self-sentiment is either an averaged single value [13] or a probabilistic mixture [10].

The COACH ICA has four input components. An overhead depth camera is used to classify individual body parts on a per-frame basis. The tracker uses a random decision forest with a simple depth feature to provide intermediate multiclass probability density functions for each sampled image pixel. The hand tracking system is used to estimate the progress of the user in the handwashing task [14]. A second camera next to the tap captures the emotional reactions of the user through their facial expressions. An open-source toolkit[2] is used for face registration and landmark detection. Continuous labeled data from the SEMAINE database[3] is used for training the 3D vector in EPA space. This component outputs the emotion of the user. A microphone captures speech output of the person, and detected words are interpreted as behaviour sentiments using a label propagation method [15]. The last channel is a static identity profile of the user that is determined through an in-person interview.

The interview tool was developed based on a longer semi-structed qualitative process [16], in which 12 older adult

[1]Funded by the American Alzheimer's Assoc. and AGE-WELL NCE Inc
[2]School of Computer Science, University of Waterloo, Canada
[3]National Core for Neuroethics, Univ. of British Columbia, Canada
[4]Department of Sociology and Criminology, Cleveland State Univ., USA

[1]values range by convention from -4.3 to $+4.3$ [12]
[2]https://github.com/TadasBaltrusaitis/OpenFace
[3]http://semaine-db.eu/

S.No.	Gender	Age	Clinical information	Biographical identities (Persona)	Persona sentiments
R01	male	63	Young-onset moderate dementia	father,husband, brother Canadian, lawyer	Father- E:1.84/P:1.78/A:0.02 Lawyer- E:0.21/P:2.09/A:0.12 Husband- E:1.15/P:1.04/A:0.10
R02	male	82	Moderate dementia	different jobs, manager, lost father in war,widow, husband - lover, father, brother	Father- E:1.84/P:1.78 /A:0.02 Salesman- E:0.33/P:0.18/A:0.73 Husband- E:1.15/P:1.04/A: 0.10 Gentleman- E:2.21/P:1.21/A:0.60
R03	female	93	Mild dementia	English, immigrant, housewife, mother, sister	Briton- E:1.25/P:0.42/A:0.27 Mother- E:2.19/P:1.75/A:0.32 Housewife- E:1.46/P:-0.24/A: 0.27

TABLE I: Characteristics of interviewed residents and their set of affective identities and associated EPA values.

Identities		Simulated best behaviour			Emotion	
ICA	User	EPA		Example	ICA	User
Nurse	Patient	2.0,1.5,0.2	Advise	"I think you should use the soap now"	cheerful	contented
Nurse	Boss	1.9,0.6,-0.2	ask about something	"Do you think you should use the soap now?"	contented	contented
Impatient Nurse	Patient	-0.5,0.7,0.2	Lecture	" Washing your hands is important - please do so now "	eager	contrite
Impatient Nurse	Boss	-0.1,-0.1,0.5	prod	"Please use the soap, its really important	eager	contrite
do- nothing	Patient	-1.2 -1.2, -1.4	Ignore	– no prompt given –	regretful	exasperated
do- nothing	Boss	-0.6,-1.7,-0.8	Beg	"please use the soap, I beg of you"	nervous	self-conscious

TABLE II: ACT behaviour and emotion predictions for different ICA and user identities.

care home residents and 12 caregivers were interviewed. The interview covered life domains (family and origin, occupation/vocation, personal history and relationships), and feelings related to an ICA. All interviews are transcribed and analyzed to extract a set of affective identities, coded according to the social-psychological principles of ACT. Preliminary results of the qualitative analysis of the interviews show that a set of identities can be extracted for each participant (e.g., father, husband). Furthermore, our results provide support for the proposition that, while identities grounded in denotative memories fade as a person loses their ability to remember people and events, affective aspects of identity in the self-sentiment may persist longer, even without situational context [17]. Table I gives an overview of demographics, identities and sentiments of three different residents who were interviewed.

These findings are replicated by simulating interactions between identities for the user and for the ICA and predicting the optimal (most aligned) behaviour for the ICA (Table II). Consider the user who thinks of himself as either a 'patient' (current identity with EPA: [0.9, -0.7, -1.0]), or a 'boss' (biographical identity with EPA: [0.5, 2.2, 0.9] as above). We simulate that the user is interpreting the virtual assistant as a 'nurse' (EPA: [1.7, 0.9, 0.3]). ACT predictions are in line with interview results: more powerful identities call for less powerful, more deferential behaviours, relayed as prompts with emotional content that conveys this power structure.

Some users ascribe more negativity in Evaluation to the nurse virtual assistant, which can be simulated with an 'impatient nurse'(EPA: [-0.5,0.2,0.1]). The outcomes of this simulation yield a difference in predicted behaviors, with the patient expecting a lecture and the boss expecting a prodding type of behaviour. In some interviews, we found residents to be more negative about the virtual assistant, stating they didn't need help from the device and didn't like it. We therefore simulate with the ICA having the identity of 'do-nothing', as this is what the user is expecting from the ICA (EPA: [-1.9,-2.0,-2.1], or quite negative, powerless and inactive). In this case, we see a significant difference in predicted behaviors. A 'patient' would expect no help from such an assistant, whereas a 'boss' would expect the virtual assistant to beg them to do something.

In collaboration with local retirement and long-term care facilities, the ICA will be tested with people with ADRD over the next two years. For each set of affective identities found in this sample of the population, a specific personalized prompting style will be programmed that reaffirms the user in his or her overall persona and situational identity. To achieve this goal, different modalities will be modified and enhanced (e.g., look and facial expression of virtual assistant, wording of prompts, tone of voice). These improvements to existing and emerging assistive technologies will ensure that their goal of increasing users' autonomy and independence and decreasing caregiver burden are maximized while the challenges of acceptability and adoption are minimized.

REFERENCES

[1] M. Prince, A. Wimo, M. Guerchet, G. Ali, Y. Wu, and M. Prina, "The global impact of dementia: An analysis of prevalence, incidence, cost and trends," *World Alzheimer Report*, 2015.

[2] H. M. Arrighi, *et al.*, "Longitudinal changes in functional disability in alzheimer's disease patients," *International Psychogeriatrics*, 25, 6, pp. 929–937, 2013.

[3] A. Mihailidis, J. N. Boger, T. Craig, and J. Hoey, "The coach prompting system to assist older adults with dementia through handwashing: An efficacy study," *BMC geriatrics*, vol. 8, no. 1, p. 1, 2008.

[4] J. Hoey, P. Poupart, A. von Bertoldi, T. Craig, C. Boutilier, and A. Mihailidis, "Automated handwashing assistance for persons with dementia using video and a partially observable Markov decision process," *CVIU*, vol. 114, no. 5, pp. 503–519, 2010.

[5] R. Wilson, E. Rochon, A. Mihailidis, and C. Leonard, "Examining success of communication strategies used by formal caregivers assisting individuals with alzheimers disease during an activity of daily living," *J. of Speech, Language, and Hearing Res.*, 55, 2, pp. 328–341, 2012.

[6] C. J. Orona, "Temporality and identity loss due to alzheimer's disease," *Social Science & Medicine*, vol. 30, no. 11, pp. 1247–1256, 1990.

[7] D. Rose Addis and L. Tippett, "Memory of myself: Autobiographical memory and identity in alzheimer's disease," *Memory*, 12, 1, 2004.

[8] D. R. Heise, *Expressive order: Confirming sentiments in social actions*. Springer Science & Business Media, 2007.

[9] C. E. Osgood, W. H. May, and M. S. Miron, *Cross-Cultural Universals of Affective Meaning*. University of Illinois Press, 1975.

[10] J. Hoey and T. Schröder, "Bayesian affect control theory of self." in *AAAI*, 2015, pp. 529–536.

[11] J. Hoey, T. Schröder, and A. Alhothali, "Affect control processes: Intelligent affective interaction using a partially observable Markov decision process," *Artificial Intelligence*, 230, pp. 134–172, Jan. 2016.

[12] D. R. Heise, *Surveying Cultures: Discovering Shared Conceptions and Sentiments*. Wiley, 2010.

[13] D. Heise and N. MacKinnon, *Self, identity, and social institutions*. Springer, 2010.

[14] S. Czarnuch *et al.*, "The design of intelligent in-home assistive technologies: Assessing the needs of older adults with dementia and their caregivers," *Gerontechnology*, 10, 3, pp. 169–182, 2011.

[15] A. Alhothali and J. Hoey, "Semi-supervised affective meaning lexicon expansion using semantic and distributed word representations," *arXiv preprint arXiv:1703.09825*, 2017.

[16] A. König, L. E. Francis, J. Joshi, J. M. Robillard, and J. Hoey, "Qualitative study of affective identities in dementia patients for the design of cognitive assistive technologies," *Journal of Rehabilitation and Assistive Technologies Engineering*, 2017.

[17] L. Caddell and L. Clare, "I'm still the same person: The impact of early-stage dementia on identity," *Dementia*, vol. 10, p. 379-398, 2011.