

Emotion Recognition in Dementia: Advancing technology for multimodal analysis of emotion expression in everyday life

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Abstract—This paper provides an overview of my PhD project that focuses on recognizing emotions in dementia by analyzing multi-modal expressions in autobiographical memories of older adults with dementia. The project aims for a better understanding how dementia influences emotional expressions and how dementia differs from the normal aging process. For this reason, spontaneous emotions will be elicited in autobiographical memories in two groups of older adults, one with dementia the other without, for comparison. Audio, video and physiological data will be collected at their home resulting in real-life environments. The emotional expressions can then be analyzed by extracting verbal, non-verbal, facial and gestural features from the audio, video and physiological data collected. In addition, a longitudinal study will be conducted with the older adults with dementia to investigate the longitudinal effect of dementia on emotions. A database of the emotional memories of these vulnerable groups will then be developed to contribute to the advancement of technologies for (automatic) multi-modal emotion recognition. The database will then be made available for the research community. Lastly, we will also develop visualization and statistical models to assess multi-modal patterns of emotion expression in these groups.

Index Terms—emotions, spontaneous, older adults, dementia, multi-modal, old age, autobiographical memories, affective computing

I. INTRODUCTION

Dementia is a group of neurodegenerative diseases that affects cognitive processing. Nowadays, more than 270.000 persons have dementia in the Netherlands. It will grow intensively to more than half a million in 2040 [1]. Besides problems in cognitive functioning, 80-90% of the patients also suffer from problems in emotional functioning. It is important to gain more insight in the emotional functioning of persons with dementia as it is highly important to maintain quality of life in person-centered care. Current research uses observational instruments to assess emotional functioning in persons with dementia such as the Neuropsychiatric Inventory [2] or the Well-Being Index-Dementia [3]. These instruments ask (informal) caregivers to rate the frequency of emotions across a certain period of time (e.g., the last week). Such summary ratings may be biased by

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particularly impactful incidents [4] as well as by characteristics of the caregiver rather than the patient [5]. Hence, they do not provide the fine-grained insights that are necessary to understand the factors influencing the expression of emotional responses of persons with dementia. These insights are needed to improve person-centered care that optimizes quality of life [6]. The current project therefore also aims to advance technologies that allow for (automatic) recognition of emotions in persons with dementia.

However, these observational instruments do not provide the fine-grained insights that are necessary to understand the factors influencing emotional responses and expressions of persons with dementia. Emotional expression is a continuous process that involves many features of behavioural, facial, vocal, and verbal modalities. Given this complexity, few psychological studies have addressed how the expressed emotions in persons with dementia can be recognized in an everyday context. Recent technological innovations in affective computing aim to take the complexities of emotional expression into account. Automatic emotion recognition technology makes it therefore possible to study latent features that are difficult to observe and track by human beings between different modalities. It also allows us to investigate larger sets of video data in a smaller amount of time and for unobtrusive analysis and monitoring of everyday emotions. However, little is known about how these lab-based technologies generalize to real-life settings for people with dementia. Rather than a one-size-fits-all-solution, existing technology should be adapted to specific user groups in more natural settings and it also needs to take large individual differences of people with dementia into account.

II. BACKGROUND

Despite the importance of emotional functioning for the quality of life and care of persons with dementia, there are few studies on emotional expression in dementia, which focus on the production of emotions in people with dementia. With regards to emotions and dementia, more research has focused on the recognition of emotion, which focus on how well people

with dementia can recognize emotions (i.e., perception), or has focused on diagnosing dementia based on different modalities. The few studies on emotional expression in dementia were often fixated on one modality, namely facial expressions, but other modalities have not yet been studied such as non-verbal speech or the combination of different modalities. The current studies on facial emotional expressions in dementia used manual coding of e.g. taxonomies of the face to study facial muscle movement of emotions or expressive emotional behavior in the face or electrodes to study the activation of facial muscles [7]–[11].

Emotions are complex phenomena. Emotional expression is characterized by several modalities, including changes in bodily action tendencies, facial expressions, and vocalizations [12]. Each modality of emotion expression itself is made up of several features. Behavioral expressions are based on action tendencies that accompany emotions, such as *flight* in the case of *anxiety* or *fight* in the case of *anger*, but they also entail distinct behaviors like gesticulation, sighing, and laughter. Facial expressions are based on facial muscle movements, which are also known as action units. These are observed and classified as emotional expressions based on a taxonomy of facial configurations [13]. Vocal expressions include prosodic phenomena like pitch, vocal quality, or timing aspects that are mainly related to levels of emotional arousal whereas verbal expressions include explicit and implicit references to the experience of positive or negative emotional states. Emotional expression is thus a complex process, involving the interaction between several modalities. This is further complicated by the fact that emotional expression is a continuous process in time as emotions are transient alterations in relation to the flow of changes in everyday life [14]. The field of affective computing aims to take these complexities of emotional expression into account [15]. Automatic emotion detection makes it possible 1) to investigate much larger sets of video data in a smaller amount of time, 2) to make latent features that are difficult to observe and track by human beings explicit and 3) to allow for unobtrusive analysis and monitoring of everyday emotions in older adults with dementia.

III. RESEARCH PROBLEM

Current technology in the affective computing domain is available to automatically detect behavioral, facial, vocal, and verbal expressions of emotions separately. However, there are several methodological challenges with regard to our target group.

The first is that existing research for automatic emotion detection has been largely tested in lab-based contexts, often focusing on emotional expressions of actors or younger adults. Hence, little is known on how they generalize to real world problems [15]. Existing tools need to be adapted to these vulnerable groups in more natural settings.

Second, different modalities hold somewhat different information about emotional states that might complement, substitute or even contradict one another resulting in co-occurrence or blends of emotions. Although a recent meta-

analysis has shown that combining information from different modalities increases the accuracy of emotion recognition [15], little is known yet on how the information derived from different modalities should be fused [16]. Although it has been found that people with dementia can still express basic emotions [9], dementia may impact emotional expression in different ways [17]. Cognitive impairments may influence the rate and duration of emotional expressions. They also may have a differential influence on the intensity of different emotions as well as on the different modalities of emotional expression.

This leads to the third challenge as large individual differences exist in intensities and durations of different modalities of emotional expression [18], a problem that was encountered in previous studies that tried to bring affective computing to real world situations [19]. To address these challenges, this PhD research project aims to take these intricacies of multi-modal expression of emotions into account to advance the automatic analysis of emotional expression in dementia.

IV. RESEARCH OBJECTIVES AND CONTRIBUTIONS

A. Research Objectives

Our primary objective is to gain more insight in how dementia affects multi-modal patterns of emotion expression. The first primary objective is to investigate how these patterns differ between persons with dementia of the Alzheimer type and healthy older adults whereas the second primary objective is to study how multi-modal patterns of emotion expression develop over time in persons with dementia of the Alzheimer type. Our secondary objective is to advance the field of affective computing by exploring machine learning for the automatic recognition of emotional expression based on the fusion of features of multi-modalities in persons with dementia. Our third objective is to develop a corpus that can be used by other researchers that are interested in exploring emotional expressions in people with dementia.

B. Possible Research Contributions

As described in section III, there are still under-explored matters and gaps in the fields of dementia research and affective computing research that leave room for investigation. This PhD research project will contribute to these fields by presenting a novel spontaneous Dutch multi-modal database consisting of emotional memories of older adults and older adults with dementia. This will contribute to the lack of spontaneous multi-modal emotion database of these vulnerable groups. It also makes it possible to use and improve automatic emotion recognition technology for these groups. The improved automatic recognition technology can then also be used in dementia research. Also, multi-modal analysis of spontaneous emotional expressions in face, speech and gestures in real-life settings can be conducted with the database. In addition, a novel annotation scheme for emotional memories to label spontaneous emotions will be developed that can be used by other researchers.

V. RESEARCH METHODOLOGY

To achieve the objectives as described in section IV, the research is comprised of the following studies: We carry out a comparative study between older adults with early-mild dementia of the Alzheimer type and matched healthy older adults. The aim of this study is to compare differences in persons with dementia of the Alzheimer type and healthy controls (first primary research objective). Next, we carry out a longitudinal study on the development of emotion expression in older adults with dementia across time. The aim of the longitudinal study is to gain insight in the development of emotional expression in dementia over time (second primary research objective). The comparative study serves as the baseline measurement for the longitudinal study. The longitudinal study will have three additional measurement points: three months, six months, and twelve months after baseline. The methods used in this research project will now be discussed.

A. Eliciting Methods

In order to study emotions in dementia, the method for emotion induction should be personally meaningful and rich in contextual detail for people with dementia [20]. Unlike other aspects of cognitive functioning, autobiographical memory remains relatively intact across the course of the disease [21]. Although autobiographical memories also become compromised as a result of cognitive impairments, most people - even in the moderate or severe stages of dementia - are able to construct a narrative about autobiographical memories that enabled them to preserve aspects of their self and identity [22]. Studies on reminiscence have shown that personalized memory prompts, like photos, movies, or music stimulate the recollection of autobiographical memories in dementia [23]. In this PhD research project, the accuracy of memories is less important than their ability to raise emotions. Reminiscence about the past is often used in dementia care and has positive effects on emotional functioning in older adults with dementia [24]. The Autobiographical Memory Test (AMT) and the Life Story Book (LSB) will be used to recollect emotional memories. For comparative purposes, the International Affective Picture System (IAPS) will also be used to elicit emotions. Across the three elicitation methods, two emotional states (sad and happy) are used to assess autobiographical memories and responses to emotional pictures. These emotions differ across the two most important dimensions of emotional expression, i.e., valence and level of arousal. Furthermore, these emotions are directly relevant in dementia care.

B. Annotation of qualitative data

To address the primary and secondary objectives concerning emotion expression, the analyses start with the annotation of the memories. The emotional memories shared by older adults and older adults with dementia will be transcribed. Next, the memories are divided into chunks that describe a meaningful and coherent part of the memory. These chunks are used as unit of analysis. Each unit of analysis can be manually coded for characteristics of autobiographical memories (e.g.,

vividness, specificity, perspective, and valence). These codes are coded based on existing annotation schemes that are adapted to the current study. The inter-rater reliability will be checked by having multiple raters code the memories. Furthermore, emotional expression (labels and descriptions regarding valence for example) is coded for each unit of analysis with a new developed annotation scheme for emotional memories.

C. Extraction of relevant features for quantitative data

The multi-modal expressions are facial, vocal, behavioural, and verbal expressions in this PhD research project. We will use automated analysis of the different modalities in the following ways:

Facial expressions: Video recordings will be used to analyse the facial expressions of persons with dementia and healthy older adults. The automatic feature extraction of FACS codes will be used via software such as OpenFace [25].

Vocal expressions: Audio recordings of the participant and principal investigator will be used to analyse non-verbal expressions in speech. Automatic feature extraction software such as Praat [26] and others will be used to extract for example pitch, intensity, energy, melscale frequency cepstral coefficient (MFCC), pause duration and silences.

Behavioral expressions: Data of an accelerometer located on the wrist of the older adult will be recorded. The data will be used to study the bodily expression of emotions, which can show how persons with dementia communicate emotions through gestures or posture. Movement variables could be for example acceleration, velocity or jerk movements that can be affected by emotions [27].

Verbal expressions: Text analysis based on transcripts of the audio recordings will be done in which for example Linguistic Inquiry and Word Count (LIWC) analysis can be applied to analyse the use of words, use of emotional words and word count [28]. In addition, lexical analysis such as sentiment analysis is performed at the transcripts [29].

VI. PAST WORK

We conducted the study of emotions and healthy older adults (N=23) by collecting autobiographical emotional memories in two sessions. For the first session, we recorded only the audio. Audio, video and physiological data were recorded for the second session [30]. Then, the data collected in this study was used to create a spontaneous Dutch Multi-Modal Emotional Memories of Older Adults (MEMOA) database. A first attempt to label emotions in the database was made by developing a novel annotation scheme for valence in emotional memories. Using the MEMOA database and emotional valence labels, we conducted a first analysis in vocal and verbal expressions with regards to valence in emotional memories. We found that valence could be predicted by several acoustic and lexical features. However, the results also revealed that emotional intensity acted as a possible confounder [30]. The past work on older adults will be used as the input for the comparative study with older adults with dementia in future work.

VII. CURRENT WORK

At the moment, we are in the process of receiving medical ethical approval for the longitudinal study (1 year) of emotions and older adults with dementia to extend the current MEMOA database. The longitudinal study will start at 01-08-2019 and will end at 01-02-2021. We are also annotating the database for emotions (i.e., valence and emotional intensity). In addition, we are examining characteristics of autobiographical memories. We are further exploring the database by analysing the multi-modalities of speech, facial and gestures with regards to emotional expressions in older adults' emotional memories. Additionally, the MEMOA database is currently being processed to be made available to the research community.

VIII. FUTURE WORK

The emotional expressions of older adults and older adults with dementia will be compared to examine the influence of dementia on emotions in comparison to the normal aging process. Also, we will further develop the annotation scheme for spontaneous emotions in memories. Additionally, the influence of dementia on emotions will be investigated by studying the longitudinal data (i.e., emotional memories) in multiple sessions over a year of older adults with dementia to see if the emotional expressions change over time when dementia progresses. Eventually, we aim to automatically recognize emotions in older adults and older adults with dementia by exploring machine learning techniques.

IX. ADVICE SOUGHT

Based on previous work, a number of challenges arose that I hope the consortium can provide advice on or sharing similar insights related to the following challenges:

- Based on observations from the database, emotions can sometimes co-occur or blend when participants discussed a memory. How can we deal with the co-occurrence or blends of emotions in the data when annotating emotions, especially when they are opposites in valence (i.e., amusement and sadness)?
- Should we consider other emotional dimensions (i.e., emotional intensity) in memories? If so, how can we include them when annotating emotions in autobiographical memories?
- And how would emotional intensity be related to valence when annotating emotions? Are these two dimensions dependent or independent from each other when discussing emotional memories?
- How can we combine different modalities of expressions in a way that we can meaningfully interpret the emotions by older adults and older adults with dementia?

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