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Associations between facial expressions and observational pain in residents with dementia and chronic pain

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Abstract

Aim: To identify specific facial expressions associated with pain behaviors using the PainChek application in residents with dementia.

Design: This is a secondary analysis from a study exploring the feasibility of PainChek to evaluate the effectiveness of a social robot (PARO) intervention on pain for residents with dementia from June to November 2021.

Methods: Participants experienced PARO individually five days per week for 15 min (once or twice) per day for three consecutive weeks. The PainChek app assessed each resident's pain levels before and after each session. The association between nine facial expressions and the adjusted PainChek scores was analyzed using a linear mixed model.

Results: A total of 1820 assessments were completed with 46 residents. Six facial expressions were significantly associated with a higher adjusted PainChek score. Horizontal mouth stretch showed the strongest association with the score, followed by brow lowering parting lips, wrinkling of the nose, raising of the upper lip and closing eyes. However, the presence of cheek raising, tightening of eyelids and pulling at the corner lip were not significantly associated with the score. Limitations of using the PainChek app were identified.

Conclusion: Six specific facial expressions were associated with observational pain scores in residents with dementia. Results indicate that automated real-time facial analysis is a promising approach to assessing pain in people with dementia. However, it requires further validation by human observers before it can be used for decision-making in clinical practice.

Impact: Pain is common in people with dementia, while assessing pain is challenging in this group. This study generated new evidence of facial expressions of pain in residents with dementia. Results will inform the development of valid artificial intelligence-based algorithms that will support healthcare professionals in identifying pain in people with dementia in clinical situations.

Reporting Method: The study adheres to the CONSORT reporting guidelines.

Patient or Public Contribution: One resident with dementia and two family members of people with dementia were consulted and involved in the study design, where they provided advice on the protocol, information sheets and consent forms, and offered valuable insights to ensure research quality and relevance.

Trial Registration: Australian and New Zealand Clinical Trials Registry number (ACTRN12621000837820).

KEYWORDS

clinical trial, dementia, facial expressions, nursing, observational, pain, pain assessment

1 | INTRODUCTION

Pain is frequently reported among older people; however, identifying and assessing pain in people with dementia is challenging. Evidence shows that around 75% of residents with dementia living in residential aged care facilities (RACFs) experience chronic pain (Barry et al., 2016; Corbett et al., 2012; de Tommaso et al., 2016; van Kooten et al., 2017). Due to a limited ability to verbalize their pain experience, residents with dementia may express their pain in various ways and with altered behaviors (Atee et al., 2020; Wei et al., 2021). Impairments in memory and language impact the ability of people with dementia to communicate their pain and care needs. Therefore, residents are in danger of silent suffering from pain and being prescribed inappropriate medications, such as antipsychotics and sedatives, to manage their changed behaviors. This treatment can result in delirium and an increased risk of death (Scuteri et al., 2021).

Reliable pain recognition and assessment are essential for the effective treatment of pain. Although self-reporting is the gold standard for pain assessment, it is challenging for people with dementia as they become less verbally communicative. Therefore, observational pain tools have become more important. Behavioral pain assessment tools typically focus on direct observation of pain-related behaviors, i.e., facial expression, body posture, movement, vocalization, etc., and may include changes in behaviors and functioning as recommended by the American Geriatric Society (AGS) (AGS Panel on Persistent Pain in Older Persons, 2002). Despite many available observational pain assessment tools, healthcare professionals struggle to accurately assess pain in people with dementia due to inadequate training, insufficient time, low staffing and high staff turnover in the aged care sector (Knopp-Sihota et al., 2019). These challenges have motivated the pursuit of automated systems to support caregivers in automated pain assessment in people with dementia.

2 | BACKGROUND

There is strong evidence in the research literature that facial expressions indicate pain in people with dementia (Kunz et al., 2019; Lautenbacher et al., 2022). Commonly, pain-indicative expressions include but are not limited to facial action units (AU) such as brow lowering (AU4), cheek raise/lid tighten (AU6_7), nose wrinkle/lip raise (AU9_10), opening of the mouth (AU25_26_27) and eye closure (AU 43) (Kunz et al., 2019). A recent laboratory study showed that people with dementia have similar responses to pain pressure, and more importantly, they have increased pain-related facial responses to pain stimuli (Bunk et al., 2021). Moreover, facial pain expressions could indicate experimental-induced acute pain among people with dementia who could not articulate valid verbal pain ratings (Kunz et al., 2007). The most important predictors of this type of pain include "opened mouth," "raising upper lip," "frowning" and "narrowing eyes," which can differentiate between non-painful and painful conditions in persons with dementia (Lautenbacher et al., 2018). However, facial expressions of experimental-induced pain experience differ from clinical chronic pain manifestation (Lautenbacher & Kunz, 2017; Prajod et al., 2022). There is a lack of research on the facial expressions of pain in people with dementia in clinical situations. Furthermore, although fine-grain analysis using the Facial Action Coding System is achievable in research, it may not be feasible for clinical use in real-time because it is too time and effort-consuming in coding (i.e., 1:100 for real-time: coding time ratio) (Prkachin & Hammal, 2021). Therefore, advancements in automated facial image and video analysis inspired the application of these techniques to detect pain from facial expressions.

Automated assessment has already been developed and marketed. For example, the recently developed PainChek smart device application (www.painchek.com, PainChek Ltd, Sydney, Australia) uses artificial intelligence (AI) and facial recognition technology to identify facial expressions of pain. PainChek uses the in-built cameras to record the individual's face with smart devices (e.g., tablets or smartphones) and then detect nine pain-associated facial expressions. Specifically, the smart device camera views the person's face and conducts a 3-second video facial analysis of the images using AI-driven facial recognition. It automatically recognizes and records facial muscle movements indicative of pain. The assessor then uses PainChek's guided checklist to observe and record pain-related behaviors, including vocalizations, movement, behaviors, activity, and body language. Each feature is assessed in a binary way as being observed (score = 1) or not observed (score = 0). Finally, PainChek calculates an overall pain score and stores the result.

Promising findings have indicated the potential of PainChek in identifying pain in people with dementia (Atee et al., 2018, 2022); however, it is unclear which facial descriptors truly indicate pain in people with dementia (Kunz et al., 2020). Moreover, the existing approaches to automated facial recognition of pain are primarily based on limited young and healthy populations (Dildine &

Atlas, 2019). They may not apply to older people with dementia, as emotional blunting is particularly common in people with dementia (Lautenbacher et al., 2022; Taati et al., 2019). Furthermore, there is limited research on the facial expressions of pain in people with dementia in clinical situations. As such, more research on the facial expressions of pain from a clinical population with dementia experiencing pain is warranted. In summary, it is necessary to identify specific facial expressions indicative of pain in people with dementia. This would also improve using automated facial recognition technology for pain assessment in this population.

3 | THE STUDY

3.1 | Aim

This study aimed to identify the associations between nine pain-related facial expressions measured by the PainChek app and the adjusted observational pain scores (i.e., 33 indicators of pain behaviors of vocalizations, movement, behaviors, activity and body language) in residents with dementia and chronic pain living in nursing homes.

4 | METHODS

4.1 | Study design and participants

This study was a secondary data analysis as part of a randomized controlled trial, exploring the feasibility of the PainChek app in assessing the effectiveness of a social robot (PARO) to manage pain for people with dementia living in a RACF. The PARO is an intelligent interactive social robot with the features of a baby harp seal that can open and close its eyes, move its neck, front and rear flippers and respond to people with dementia by making a sound when it is being stroked or talked to. It can also show negative emotions on undesired stimulation, such as when being hit (Shibata et al., 2021).

Residents who met the following criteria were included in the study: (1) aged 65 years and over who can speak and understand English, (2) diagnosed with some form of dementia, (3) assumed to be experiencing chronic pain and receiving regular pain medications or evaluated through proxy reports of pain by care staff, (4) the sensation and perception to interact with PARO and (5) admitted in the facility for more than 3 months. Residents who had comorbidities that required hospital admission frequently, had terminal illnesses receiving palliative care, major mental illnesses, infectious diseases or had an open wound that could not be covered were excluded.

The facility coordinator assisted with identifying potential participants based on the selection criteria. They obtained consent from both potential participants and their legally authorized representatives to facilitate communication with researchers via email or phone calls. Subsequently, we reached out to individuals who expressed interest in joining the study. Additionally, recruitment flyers and invitation letters were distributed to further encourage participation among potential participants.

Residents eligible to participate had experienced PARO (robotic or non-robotic, i.e., without intelligence features) individually five days per week for 15 mins (once or twice) per day for three consecutive weeks. The 4-week intervention was shortened to a 3-week intervention due to restrictions on visiting aged care facilities during the COVID-19 outbreak. The study protocol was registered with the Australian and New Zealand Clinical Trials Registry database (ACTRN12621000837820) and previously published (Pu et al., 2022).

4.2 | PainChek app

The PainChek app (Figure 1) facial domain includes nine facial action units (AUs): brow lowering (AU4), cheek raising (AU6), tightening of eyelids (AU7), wrinkling of the nose (AU9), raising of the upper lip (AU10), pulling at corner lip (AU12), horizontal mouth stretch (AU20), parting lips (AU25) and closing eyes (AU43). After detecting the nine facial expressions, the assessor records residents' changes in vocalizations, movement, behaviors, activity and body language guided by a checklist. It takes around 5 min to complete one assessment. The total score ranges from 0 to 42, with each item scored as presence (1) or no (0). Four levels of pain intensity are calculated as follows: 0–6 = no pain, 7–11 = mild pain, 12–15 = moderate pain, and 16 = severe pain (Atee et al., 2018). Compared with the Abbey pain scale, the PainChek app shows good internal consistency and concurrent validity (Atee et al., 2018).

4.3 | Training of the assessors

Research assistants with backgrounds in psychology used the PainChek app to measure facial expressions and observational pain levels in residents daily using iPads. First, they received 2 h of face-to-face training on pain communication and interaction with people with dementia. Then, they completed the PainChek tool online training course (2 h) to familiarize themselves with the app and meet the regulatory standards of quality and safety. Following training, each received at least 30 min of face-to-face individual coaching from a nurse specialist in pain, dementia and the PainChek app. This involved conducting PainChek assessments on residents at the RACF to enhance their confidence in using the PainChek app.

4.4 | Data collection

The age, gender, medical diagnoses, marital status and Cultural and Linguistic Diversity (CALD) background were retrieved from residents' medical files. Cognitive function was measured by the Mini-Mental Status Examination (MMSE), where scores below 24 are

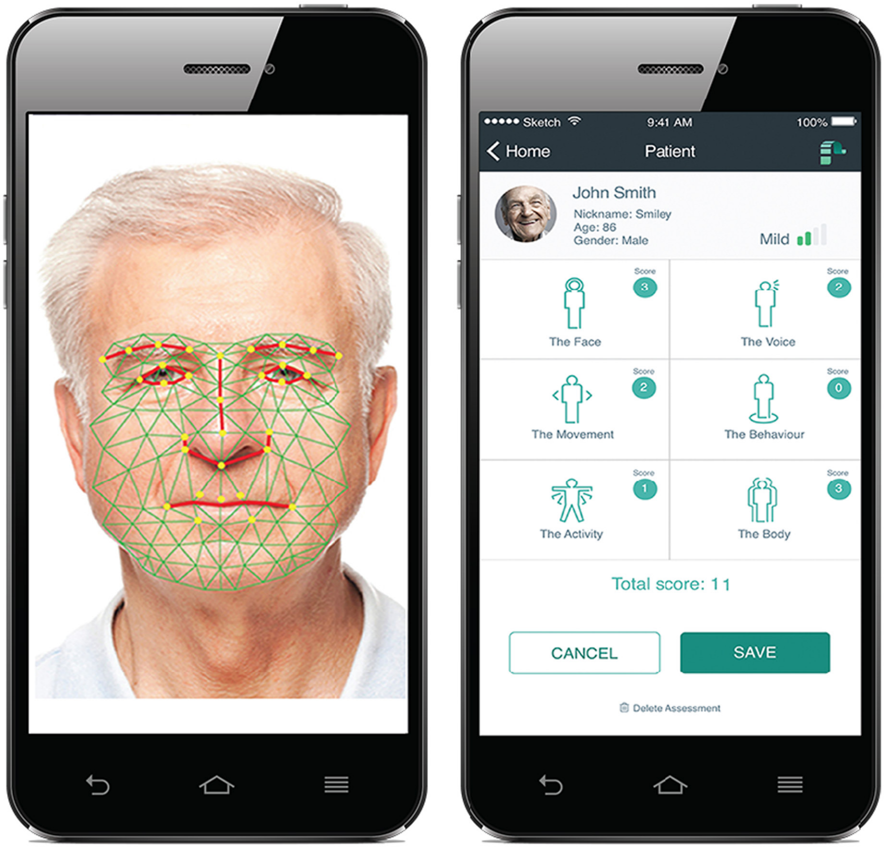

FIGURE 1 PainChek app (Permission for the image provided by Professor Jeff Hughes, Chief Scientific Officer of PainChek Ltd, Australia).

commonly used to indicate possible cognitive impairment (Monroe & Carter, 2012). Nurses recorded the observed pain levels with the Abbey Pain Scale (APS) (Abbey et al., 2004). Neuropsychiatric symptoms were recorded with the Neuropsychiatric Inventory-Nursing Home version (NPI-NH) (Wood et al., 2000). All the assessments were undertaken by two trained research assistants with a health background through structured interviews with residents, care staff and nurses familiar with residents. In addition, psychotropic and analgesic drug use (dichotomized to present or absent) was recorded from the electronic medication records.

4.5 | Data analysis

The Statistical Package for the Social Sciences (SPSS, version 27, IBM Corp. 2021) was used for data analyses. Background information, including gender (male/female), medical diagnoses and medication use, was described using frequency and percentage (%). The continuous variables were assessed for normality using the Kolmogorov–Smirnov test. The age, length of stay and MMSE score showed a normal distribution ($p > .05$), but the nurse-observed APS pain score and the NPI-NH score were not normally distributed ($p < .001$). Therefore, the mean and standard deviation (*SD*) described continuous variables with normal distribution, while the median and interquartile range (IQR) described skewed distribution data.

A linear mixed model (LMM) was used to examine the relationship between nine AUs and the adjusted observational pain scores (33 items of the behavioral pain indicators) to account for repeated, continuous and correlated observations and accommodate missing data.

The LMM examined the observational pain score as a continuous outcome, with fixed effects (Type III sum of squares) of age, MMSE score and NPI-NH score and with AUs treated as factors. Gender, diagnosis of depression or anxiety, the use of analgesics or psychotics and CALD background were also included as fixed effects. The resident identifier was set as a random effect with a variance components covariance matrix, and random intercepts in the model accounted for the correlations of repeated measures within each resident. A restricted maximum likelihood method of estimation was selected with model fit assessed by Akaike's Information Criterion (AIC), with a lower AIC indicating an improved model fit. Model residuals were inspected with normal distribution. The results with *p*-values below .05 were considered statistically significant.

4.6 | Ethics and informed consent

Griffith University Human Research Ethics Committee (reference number: 2021/221) approved this study. The approval to conduct the study was also received from the study site. For residents with dementia, written informed consent was obtained from those identified by staff as having the capacity to provide informed consent or their legally authorized representatives. We also obtained and recorded assent from participants before each session.

5 | RESULTS

5.1 | Characteristics of the sample

The facility coordinator screened 160 residents, and 67 agreed to participate in the study. Following the initial screening, 47 residents met the inclusion and exclusion criteria. One resident declined to use the PainChek app, resulting in the inclusion of 46 residents with 1820 pain assessments for the final analysis (Figure 2). There was a large variation in the number of assessments per resident (range 1–64) as this related to different contexts (e.g., group allocation, health conditions, dropouts). The mean (*SD*) age was 84.9 (6.8) years, with most residents being female (71.7%). Among the residents, 16 (34.8%) were from CALD backgrounds, including China, Vietnam, Singapore, Germany and Sweden. The mean (*SD*) MMSE score was 12.1 (8.7). The most common pain-related conditions were osteoarthritis (34/47, 72.3%) and other conditions, such as low back and leg pain. Moreover, 37 (80%) participants were diagnosed with depression and 17 (37.0%) with anxiety, respectively. Registered nurses reported that 25 residents had mild, moderate or severe pain, and the median (IQR) of the Abbey Pain Scale (total score 0–18; higher scores indicate higher levels of pain) was 3.0 (5.0). Around 60% of participants were prescribed analgesics and at least one psychotropic medication (Table 1).

5.2 | The relationship between facial expressions and the adjusted observational pain score

Significant associations between six AUs and the adjusted observational pain score were identified. Horizontal mouth stretch (AU20) showed the strongest association with the observational pain score (β=1.665; 95% CI: 1.321–2.018), followed by brow lowering (AU4, β=.755; 95% CI: 0.472–1.038), parting lips (AU25, β=.596; 95% CI: 0.331–0.860), wrinkling of the nose (AU9, β=.439; 95% CI: 0.094–0.784), raising of the upper lip (AU10, β=.398; 95% CI: 0.1–0.696) and closing eyes (AU43, β=.326; 95% CI: 0.113–0.54). However, the presence of cheek raising (AU6), tightening of eyelids (AU7) or pulling at the corner lip (AU12) did not significantly associate with the score (Table 2).

5.3 | Other factors associated with the adjusted observational pain score

As indicated in Table 2, gender was significantly associated with the adjusted observational pain score. Females scored higher scores than males (β=.385; 95% CI: 0.182–0.588). Compared to English-speaking residents, people from a CALD background had a higher pain score (β=.293; 95% CI: 0.103–0.484). Moreover, a diagnosis of anxiety was positively associated with the pain score (β=.808; 95% CI: 0.626–0.990). Although the pain score increased with a higher neuropsychiatric symptom (β=.008; 95% CI: 0.004–0.012), the

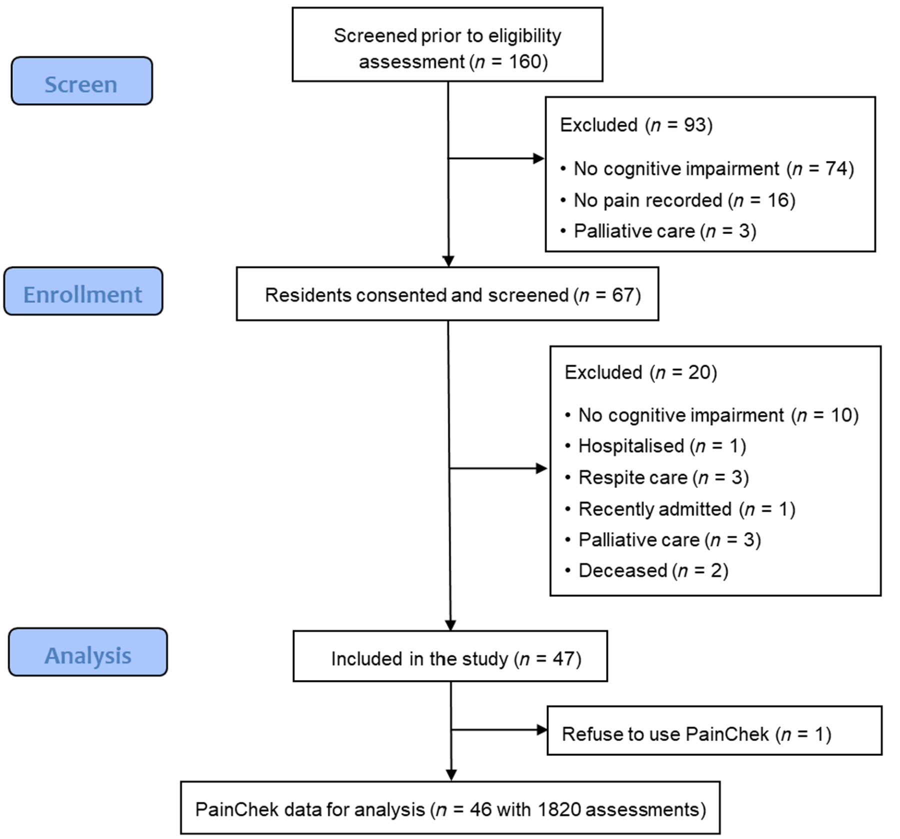

FIGURE 2 Flowchart of participant recruitment.

TABLE 1 Demographics and characteristics of participants.

Characteristics	Participants, (*n* = 46)
Age (years), mean (*SD*)	84.9 (6.8)
Gender (female), *n* (%)	33 (71.7)
CALD background, *n* (%)	16 (34.8)
Cognitive function, MMSE score, mean (*SD*)	12.1 (8.7)
Length of stay (months), mean (*SD*)	42.9 (31.0)
Dementia type, *n* (%)	
Alzheimer's disease	17 (37.0)
Vascular dementia	2 (4.3)
Mixed dementia	2 (4.3)
Frontotemporal dementia	1 (2.2)
Unspecified dementia	24 (52.1)
Marital status, *n* (%)	
Married	18 (39.1)
Widowed	23 (50)
Divorced	4 (8.7)
Single	1 (2.2)
The sensory deficit, *n* (%)	
Vision	8 (17.4)
Hearing	15 (32.6)
Vision & Hearing	5 (10.9)
Secure dementia unit, yes	3 (6.5)
Mobility, *n* (%)	
Ambulatory	5 (10.9)
Ambulatory use assistive devices	27 (58.7)
Wheelchair	7 (15.2)
Bedridden	7 (15.2)
Pain-related diagnoses at baseline[a]	
Osteoarthritis	37 (80.4)
Fracture/Fall/Injury	18 (39.1)
Back/shoulder/leg/hip pain	7 (15.2)
Other[b]	22 (47.8)
Nurse-rated pain intensity, *n* (%)	
No pain	21 (45.7%)
Mild pain	15 (32.6%)
Moderate pain	7 (15.2%)
Severe pain	3 (6.5%)
Nurse-observed pain level, APS (0–18), median (IQR)	3.0 (5.0)
NPI-NH total score (0–144), median (IQR)	9.0 (18.0)
Diagnosis with depression, yes	37 (80.4)
Diagnosis with anxiety, yes	17 (37.0)
Regular medications, *n* (%)	
Analgesics (Paracetamol and/or opioids)	27 (58.7)
Psychotropics, using at least one drug	30 (65.2)
Antipsychotics	18 (39.1)
Anxiolytics	7 (15.2)
Antidepressants	10 (21.7)
Antiepileptic drugs	8 (17.4)
Antidementia drugs	3 (6.5)

Abbreviations: APS, Abbey Pain Scale; CALD, Culturally and Linguistically Diverse; IQR, interquartile range; MMSE, Mini-Mental Status Examination; NPI-NH, Neuropsychiatric Inventory Nursing Home; *SD*, standard deviation.

[a]Each resident may have multiple pain-related diagnoses.

[b]Other including medical diagnoses of neuropathic pain, chronic pain, urinary tract infection, etc.

result had little clinical impact. Age, MMSE score, depression and medication use were not significantly related to the score.

6 | DISCUSSION

To our knowledge, this is the first clinical study we know of that identified six specific facial expressions associated with observational pain indicators in residents living with dementia and chronic pain by controlling important confounding factors, such as age, gender, ethnicity, medications, and medical comorbidities (e.g., depression and anxiety), which were largely ignored in previous studies (Anderson et al., 2021; Atee et al., 2022; Dildine & Atlas, 2019). Our findings indicate the potential of artificial intelligence-enabled real-time facial analysis as part of the pain assessment in people with dementia.

In our study, three mouth-related facial expressions, including horizontal mouth stretch (AU20), parting lips (AU25), raising of the upper lip (AU10), two eye-related facial expressions, including brow lowering (AU4) and closing eyes (AU43), and one nose-related feature wrinkling of the nose (AU9) were found to be significantly associated with a higher observational pain level. This aligns with previous findings that opening the mouth, raising the upper lip, frowning, and narrowing the eyes were the most important pain-indicative predictors (Lautenbacher et al., 2018). Similarly, the EU-COST initiative "Pain in impaired cognition, especially dementia" group developed the Pain Assessment in Impaired Cognition (PAIC) and selected four pain-related facial responses: frowning, narrowing eyes, raising upper lips, and opening mouth (van Dalen-Kok et al., 2018). Previous studies also reported that horizontal mouth stretch (AU20) was the most predictive facial pain action in people with dementia (Atee et al., 2022; Lautenbacher et al., 2018). These results suggest the importance of mouth and eye-related features as potential good facial markers of pain in dementia.

The associations between facial expressions and the observational pain score were independent of factors that may impact the perception and behaviors of pain, such as age, gender, cultural background, medication, and cognitive function. Consistent with

TABLE 2 The relationship between the presence of AUs and the adjusted observational pain scores.

Parameters	Estimate β	95% CI lower	upper	SE	*p* Value
Intercept	5.987	4.546	7.428	0.735	<.001
AU4: Brow lowering, yes[a]	0.755	0.472	1.038	0.144	<.001
AU6: Cheek raising, yes[a]	0.025	−0.152	0.201	0.090	.784
AU7: Tightening of eyelids, yes[a]	0.022	−0.176	0.220	0.101	.830
AU9: Wrinkling of the nose, yes[a]	0.439	0.094	0.784	0.176	.013
AU10: Raising of the upper lip, yes[a]	0.398	0.100	0.696	0.152	.009
AU12: Pulling at the corner lip, yes[a]	−0.159	−0.333	0.015	0.089	.073
AU20: Horizontal mouth stretch, yes[a]	1.665	1.312	2.018	0.180	<.001
AU25: Parting lips, yes[a]	0.596	0.331	0.860	0.135	<.001
AU43: Closing eyes, yes[a]	0.326	0.113	0.540	0.109	.003
Age	0.004	−0.010	0.019	0.007	.572
Gender, female[b]	0.385	0.182	0.588	0.104	<.001
CALD background, yes[a]	0.293	0.103	0.484	0.097	.003
Depression, yes[a]	−0.230	−0.465	0.006	0.120	.056
Anxiety, yes[a]	0.808	0.626	0.990	0.093	<.001
NPI-NH score	0.008	0.004	0.012	0.002	<.001
MMSE score	0.003	−0.007	0.013	0.005	.563
Analgesics, yes[a]	0.117	−0.077	0.312	0.099	.237
Psychotropics, yes[a]	−0.205	−0.423	0.013	0.111	.065

Abbreviations: AU, action units; CALD, Culturally and Linguistically Diverse; CI, confidence interval; MMSE, Mini-Mental State Examination; NPI-NH, Neuropsychiatric Inventory Nursing Home; SE, Standard Error; β, standard coefficient.

[a]Compared to an absence of the parameter.

[b]Compared to male.

previous findings, female residents had a significantly higher pain score (Atee et al., 2022). Furthermore, residents from a CALD background had a higher observational pain score. Culture and ethnicity impact people's attitudes, emotions, and behavioral responses to pain (Dildine & Atlas, 2019). These factors could also impact their facial expression of pain (Ford et al., 2015). Moreover, very few studies have explored the differences in automated facial expressions of pain between males and females, people from different cultural and ethical backgrounds, and the interactions in the clinical context for people with dementia. The importance of coding pain intensity for assessing the differences in pain responses related to age, ethnicity, or medical conditions to develop algorithms for automated technology has been previously highlighted in an editorial paper (Dildine & Atlas, 2019).

6.1 | Limitations of the PainChek app

Facial expressions to detect pain in people with dementia may be feasible as part of the assessment indicators. However, some issues and challenges in using the PainChek app to detect facial expressions of pain exist. First, PainChek relies on a small number of AUs with only binary outcomes (presence or absence) available. This could result in false negative and false positive errors because some of the AUs in the PainChek can also occur in positive (e.g., happy) and negative expressions (e.g., disgust, anger, etc.), depending on the other AUs present (Du et al., 2014). Thus, simply adding up the AUs cannot resolve the ambiguities of the facial expressions. Furthermore, analyzing each facial expression with different intensity levels is recommended. For example, the Solomon Pain Intensity (Prkachin & Solomon, 2008) score uses a pain measurement metric combining the intensities of facial expressions on a 0–5 ordinal scale. This method is commonly used in manually coding facial expressions using the Facial Action Coding System (Prkachin & Hammal, 2021).

6.2 | Implications for practice

Facial expressions could be a “late signaling system” in pain situations (Prkachin & Hammal, 2021). Moreover, empirical studies showed that many people could be facially completely unresponsive during pain in clinical settings (Kunz et al., 2021). Therefore, an absence of certain facial expressions may not mean that pain does not exist. Kunz et al. also highlighted the importance of inter-individually different faces of pain as there is a “stoic” pattern with a considerable number of people who may not display any facial expressions during painful situations (Kunz et al., 2021; Kunz &

Lautenbacher, 2014). Given this, it is recommended to conduct pain detection by focusing on facial expression and assessing behavioral indicators, such as body movements and vocalization. Furthermore, it is recommended to identify pain-indicative facial expressions with a more individualized approach to account for person-specific characteristics. Researchers have attempted to develop a personalized automated estimation of pain intensity from facial expressions using machine-learning approaches (Martinez et al., 2017; Xu & Sa, 2021).

6.3 | Implications for further research

The existing facial analysis methods are primarily built on experimentally induced pain with limited and unrepresentative samples of the young population in ideal lab settings with stable front views and bright lighting. These factors significantly challenge the generalization and application of automated facial recognition of pain in people with dementia in clinical practice, such as in nursing homes with uncooperative residents with severe behavioral symptoms or in dark lighting conditions. Addressing the challenges noted above will require detailed observation by trained human eyes of variations in pain-elicited responses and changes over time, and sophisticated automated facial evaluation and analysis instruments.

6.4 | Study limitations

This study has several limitations. We could not compare facial expressions with self-reported pain from residents with advanced stages of dementia or the nurse-observed Abbey pain. The Abbey pain scales were only obtained once at baseline due to the shortage of staff at the RACF during the Covid-19 pandemic. Furthermore, we only collected data from one Australian RACF. Therefore, our findings may not apply to different environments or healthcare settings. However, participants in this study were from a multicultural background, representing the characteristics of residents in Australian aged care. Moreover, we could not identify specific types of pain in participants, and different types of pain may impact the pain responses in facial expressions (Defrin et al., 2015).

7 | CONCLUSION

Pain assessment in people with dementia is challenging due to limitations regarding self-report. We found that the presence of six specific facial expressions is significantly related to a higher pain score based on behavioral observations. These facial expressions were independent of age, gender, cognitive impairment and cultural background, which indicates the potential of automated real-time facial analysis as part of the pain assessment in people with dementia. However, more research is still required to develop new and valid AI-based algorithms that can be applied to support healthcare professionals in identifying pain in people with dementia in nursing homes.

AUTHOR CONTRIBUTIONS

W. Moyle and L. Pu conceived and designed the overall research project in consultation with M. Coppieters, M. Smalbrugge, C. Jones, J. Byrnes and M. Todorovic. L. Pu oversaw the data collection. W. Moyle and L. Pu analyzed the data and prepared the first manuscript draft. All authors have agreed on the final version and meet at least one of the following criteria (recommended by the ICMJE*): (1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content. *http://www.icmje.org/recommendations/.

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CONFLICT OF INTEREST STATEMENT

No conflict of interest has been declared by the author(s).

PEER REVIEW

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DATA AVAILABILITY STATEMENT

Research data are not shared with no participant's permission to share data beyond this study.

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REFERENCES

Abbey, J., Piller, N., De Bellis, A., Esterman, A., Parker, D., Giles, L., & Lowcay, B. (2004). The Abbey pain scale: A 1-minute numerical indicator for people with end-stage dementia. *International Journal of Palliative Nursing*, *10*(1), 6–13. https://doi.org/10.12968/ijpn.2004.10.1.12013

AGS Panel on Persistent Pain in Older Persons. (2002). The management of persistent pain in older persons. *The American Journal of Geriatric Psychiatry*, *50*(6 Suppl), S205–S224. https://doi.org/10.1046/j.1532-5415.50.6s.1.x

Anderson, A. R., Hyden, K., Failla, M. D., & Carter, M. A. (2021). Policy implications for pain in advanced Alzheimer's disease. *Pain Management Nursing*, *22*(1), 3–7. https://doi.org/10.1016/j.pmn.2020.06.005

Atee, M., Hoti, K., Chivers, P., & Hughes, J. D. (2022). Faces of pain in dementia: Learnings from a real-world study using a technology-enabled pain assessment tool. *Frontiers in Pain Research (Lausanne)*, *3*, 827551. https://doi.org/10.3389/fpain.2022.827551

Atee, M., Hoti, K., & Hughes, J. D. (2018). A technical note on the PainChek system: A web portal and mobile medical device for assessing pain in people with dementia. *Frontiers in Aging Neuroscience*, *10*, 117. https://doi.org/10.3389/fnagi.2018.00117

Atee, M., Morris, T., Macfarlane, S., & Cunningham, C. (2020). Pain in dementia: Prevalence and association with neuropsychiatric behaviors. *Journal of Pain and Symptom Management*, *61*, 1215–1226. https://doi.org/10.1016/j.jpainsymman.2020.10.011

Barry, H. E., Parsons, C., Passmore, A. P., & Hughes, C. M. (2016). Exploring the prevalence of and factors associated with pain: A cross-sectional study of community-dwelling people with dementia. *Health & Social Care in the Community*, *24*(3), 270–282. https://doi.org/10.1111/hsc.12204

Bunk, S., Zuidema, S., Koch, K., Lautenbacher, S., De Deyn, P. P., & Kunz, M. (2021). Pain processing in older adults with dementia-related cognitive impairment is associated with frontal neurodegeneration. *Neurobiology of Aging*, *106*, 139–152. https://doi.org/10.1016/j.neurobiolaging.2021.06.009

Corbett, A., Husebo, B., Malcangio, M., Staniland, A., Cohen-Mansfield, J., Aarsland, D., & Ballard, C. (2012). Assessment and treatment of pain in people with dementia. *Nature Reviews Neurology*, *8*(5), 264–274. https://doi.org/10.1038/nrneurol.2012.53

de Tommaso, M., Arendt-Nielsen, L., Defrin, R., Kunz, M., Pickering, G., & Valeriani, M. (2016). Pain in neurodegenerative disease: Current knowledge and future perspectives. *Behavioral Neurology*, *2016*, 1–14. https://doi.org/10.1155/2016/7576292

Defrin, R., Amanzio, M., de Tommaso, M., Dimova, V., Filipovic, S., Finn, D. P., Gimenez-Llort, L., Invitto, S., Jensen-Dahm, C., & Lautenbacher, S. (2015). Experimental pain processing in individuals with cognitive impairment: Current state of the science. *Pain*, *156*(8), 1396–1408. https://doi.org/10.1097/j.pain.0000000000000195

Dildine, T. C., & Atlas, L. Y. (2019). The need for diversity in research on facial expressions of pain. *Pain*, *160*(8), 1901–1902. https://doi.org/10.1097/j.pain.0000000000001593

Du, S., Tao, Y., & Martinez, A. M. (2014). Compound facial expressions of emotion. *Proceedings of the National Academy of Sciences*, *111*(15), E1454–E1462. https://doi.org/10.1073/pnas.1322355111

Ford, B., Snow, A. L., Herr, K., & Tripp-Reimer, T. (2015). Ethnic differences in nonverbal pain behaviors observed in older adults with dementia. *Pain Management Nursing*, *16*(5), 692–700. https://doi.org/10.1016/j.pmn.2015.03.003

Knopp-Sihota, J. A., Dirk, K. L., & Rachor, G. S. (2019). Factors associated with pain assessment for nursing home residents: A systematic review and meta-synthesis. *Journal of the American Medical Directors Association*, *20*(7), 884–892. https://doi.org/10.1016/j.jamda.2019.01.156

Kunz, M., de Waal, M. W. M., Achterberg, W. P., Gimenez-Llort, L., Lobbezoo, F., Sampson, E. L., van Dalen-Kok, A. H., Defrin, R., Invitto, S., Konstantinovic, L., Oosterman, J., Petrini, L., van der Steen, J. T., Strand, L. I., de Tommaso, M., Zwakhalen, S., Husebo, B. S., & Lautenbacher, S. (2020). The pain assessment in impaired cognition scale (PAIC15): A multidisciplinary and international approach to develop and test a meta-tool for pain assessment in impaired cognition, especially dementia. *European Journal of Pain*, *24*(1), 192–208. https://doi.org/10.1002/ejp.1477

Kunz, M., & Lautenbacher, S. (2014). The faces of pain: A cluster analysis of individual differences in facial activity patterns of pain. *European Journal of Pain*, *18*(6), 813–823. https://doi.org/10.1002/j.1532-2149.2013.00421.x

Kunz, M., Meixner, D., & Lautenbacher, S. (2019). Facial muscle movements encoding pain—A systematic review. *Pain*, *160*(3), 535–549. https://doi.org/10.1097/j.pain.0000000000001424

Kunz, M., Prkachin, K., Solomon, P. E., & Lautenbacher, S. (2021). Faces of clinical pain: Inter-individual facial activity patterns in shoulder pain patients. *European Journal of Pain*, *25*(3), 529–540. https://doi.org/10.1002/ejp.1691

Kunz, M., Scharmann, S., Hemmeter, U., Schepelmann, K., & Lautenbacher, S. (2007). The facial expression of pain in patients with dementia. *Pain*, *133*(1–3), 221–228. https://doi.org/10.1016/j.pain.2007.09.007

Lautenbacher, S., Hassan, T., Seuss, D., Loy, F. W., Garbas, J.-U., Schmid, U., & Kunz, M. (2022). Automatic coding of facial expressions of pain: Are we there yet? *Pain Research & Management*, *2022*, 6635496. https://doi.org/10.1155/2022/6635496

Lautenbacher, S., & Kunz, M. (2017). Facial pain expression in dementia: A review of the experimental and clinical evidence. *Current Alzheimer Research*, *14*(5), 501–505. https://doi.org/10.2174/1567205013666160603010455

Lautenbacher, S., Walz, A. L., & Kunz, M. (2018). Using observational facial descriptors to infer pain in persons with and without dementia. *BMC Geriatrics*, *18*(1), 88. https://doi.org/10.1186/s12877-018-0773-8

Martinez, D., Ognjen, R. O., & Picard, R. (2017). *Personalized Automatic Estimation of Self-Reported Pain Intensity from Facial Expressions* 2017 IEEE Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), Honolulu, HI, USA, 2017 (pp. 2318–2327).

Monroe, T., & Carter, M. (2012). Using the Folstein mini mental state exam (MMSE) to explore methodological issues in cognitive aging research. *European Journal of Ageing*, *9*(3), 265–274. https://doi.org/10.1007/s10433-012-0234-8

Prajod, P., Huber, T., & André, E. (2022). Using Explainable AI to Identify Differences Between Clinical and Experimental Pain Detection Models Based on Facial Expressions. MultiMedia Modeling, Cham.

Prkachin, K. M., & Hammal, Z. (2021). Computer mediated automatic detection of pain-related behavior: Prospect, progress, perils. *Frontiers in Pain Research (Lausanne)*, *2*, 788606. https://doi.org/10.3389/fpain.2021.788606

Prkachin, K. M., & Solomon, P. E. (2008). The structure, reliability and validity of pain expression: Evidence from patients with shoulder pain. *Pain*, *139*(2), 267–274. https://doi.org/10.1016/j.pain.2008.04.010

Pu, L., Coppieters, M. W., Byrnes, J., Jones, C., Smalbrugge, M., Todorovic, M., & Moyle, W. (2022). Feasibility study protocol of the PainChek app to assess the efficacy of a social robot intervention for people with dementia. *Journal of Advanced Nursing*, *78*(2), 587–594. https://doi.org/10.1111/jan.15106

Scuteri, D., Vulnera, M., Piro, B., Bossio, R. B., Morrone, L. A., Sandrini, G., Tamburin, S., Tonin, P., Bagetta, G., & Corasaniti, M. T. (2021). Pattern of treatment of behavioral and psychological symptoms of dementia and pain: Evidence on pharmacoutilization from a large real-world sample and from a centre for cognitive disturbances and dementia. *European Journal of Clinical Pharmacology*, *77*(2), 241–249. https://doi.org/10.1007/s00228-020-02995-w

Shibata, T., Hung, L., Petersen, S., Darling, K., Inoue, K., Martyn, K., Hori, Y., Lane, G., Park, D., Mizoguchi, R., Takano, C., Harper, S., Leeson, G. W., & Coughlin, J. F. (2021). PARO as a biofeedback medical device for mental health in the COVID-19 era. *Sustainability*, *13*(20), 11502. https://www.mdpi.com/2071-1050/13/20/11502

Taati, B., Zhao, S., Ashraf, A. B., Asgarian, A., Browne, M. E., Prkachin, K. M., Mihailidis, A., & Hadjistavropoulos, T. (2019). Algorithmic bias in clinical populations—Evaluating and improving facial analysis technology in older adults with dementia. *IEEE Access*, *7*, 25527–25534. https://doi.org/10.1109/ACCESS.2019.2900022

van Dalen-Kok, A. H., Achterberg, W. P., Rijkmans, W. E., Tukker-van Vuuren, S. A., Delwel, S., de Vet, H. C., Lobbezoo, F., & de Waal, M. W. (2018). Pain assessment in impaired cognition (PAIC): Content validity of the Dutch version of a new and universal tool to measure pain in dementia. *Clinical Interventions in Aging*, *13*, 25. https://doi.org/10.2147/CIA.S144651

van Kooten, J., Smalbrugge, M., van der Wouden, J. C., Stek, M. L., & Hertogh, C. M. P. M. (2017). Prevalence of pain in nursing home residents: The role of dementia stage and dementia subtypes. *Journal of the American Medical Directors Association*, *18*(6), 522–527. https://doi.org/10.1016/j.jamda.2016.12.078

Wei, Y. J., Chen, C., Fillingim, R. B., DeKosky, S. T., Schmidt, S., Pahor, M., Solberg, L., & Winterstein, A. G. (2021). Uncontrolled pain and risk for depression and behavioral symptoms in residents with dementia. *Journal of the American Medical Directors Association*, *22*, 2079–2086.e5. https://doi.org/10.1016/j.jamda.2021.05.010

Wood, S., Cummings, J. L., Hsu, M.-A., Barclay, T., Wheatley, M. V., Yarema, K. T., & Schnelle, J. F. (2000). The use of the neuropsychiatric inventory in nursing home residents: Characterization and measurement. *The American Journal of Geriatric Psychiatry*, *8*(1), 75–83. https://doi.org/10.1097/00019442-200002000-00010

Xu, X., & Sa, V. R. d. (2021). Personalized Pain Detection in Facial Video with Uncertainty Estimation. 2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC) (pp. 4163–4168). https://doi.org/10.1109/EMBC46164.2021.9631056

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