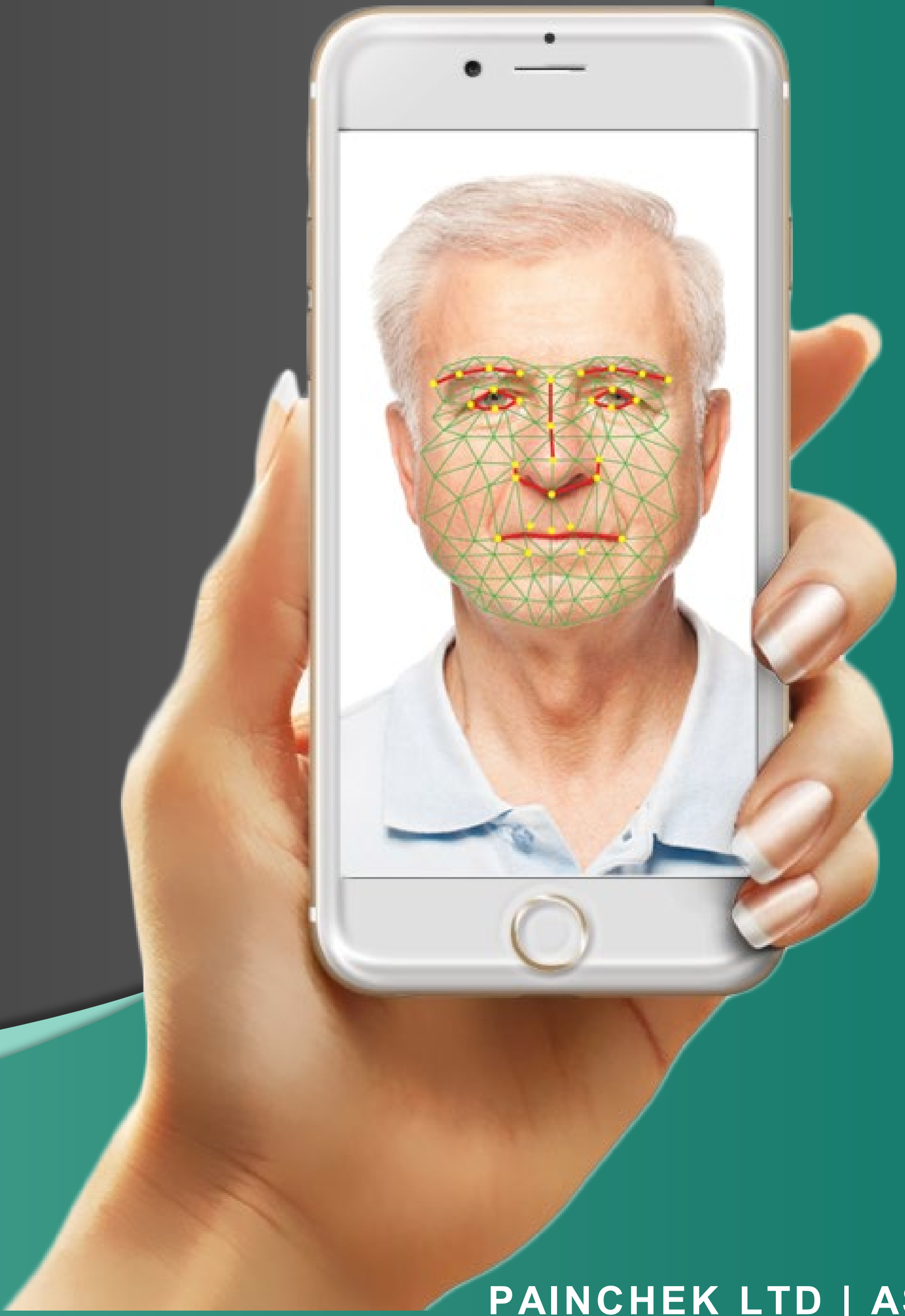
PainChek®

Intelligent Pain Assessment

AI Technology to Support Pain Assessment: The PainChek Story

Gerontech Innovation Expo and Summit November 2021



EMERITUS PROF JEFF HUGHES, CSO

Why?

Pain is common in people with dementia

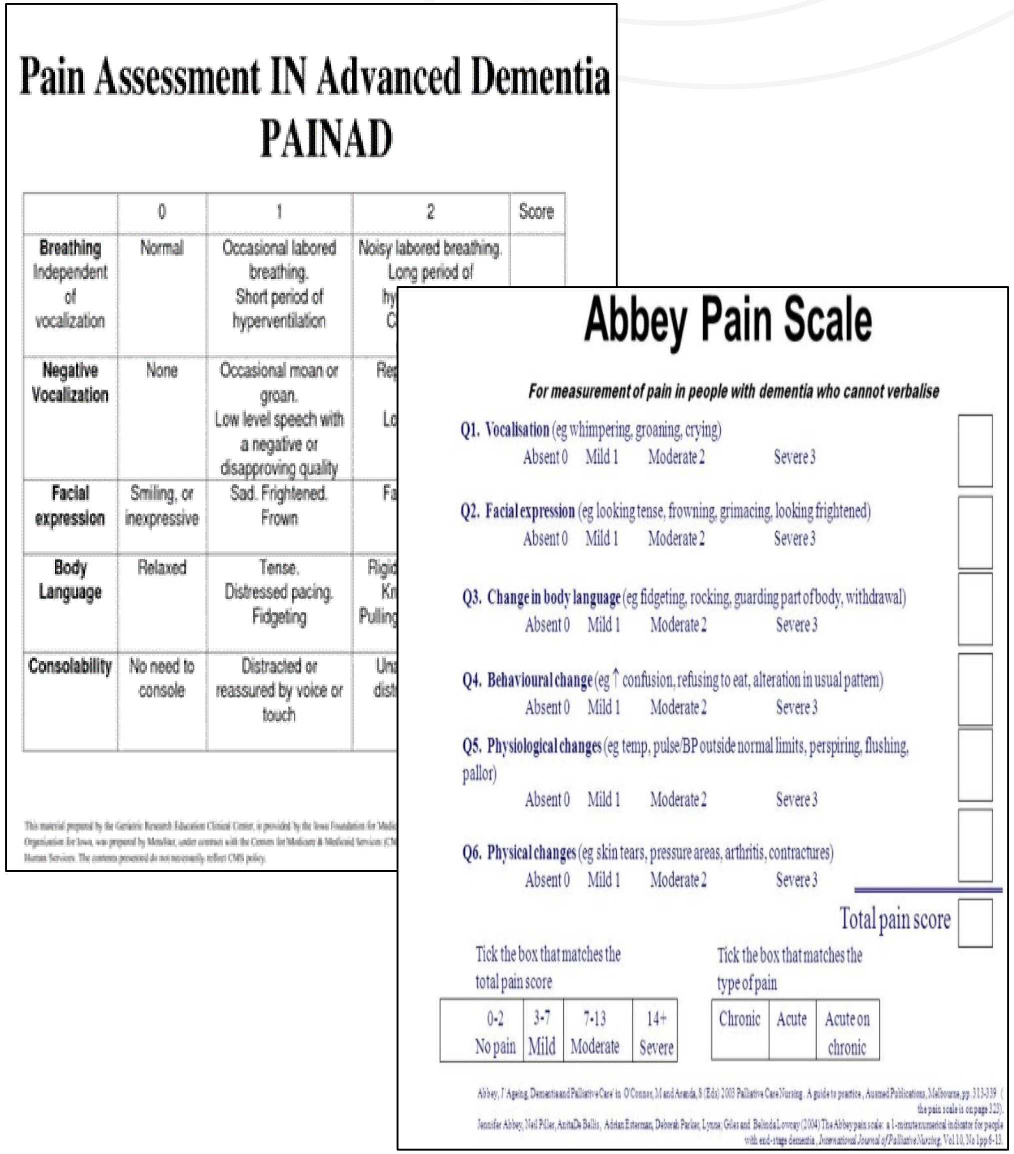
- Up to 80% of people in aged care experience chronic pain

Pain assessment is challenging

- Impaired cognition and communication abilities

Current pain assessment tools

- Sub-optimal
- Lack consistency
- Subjective
- Underutilized

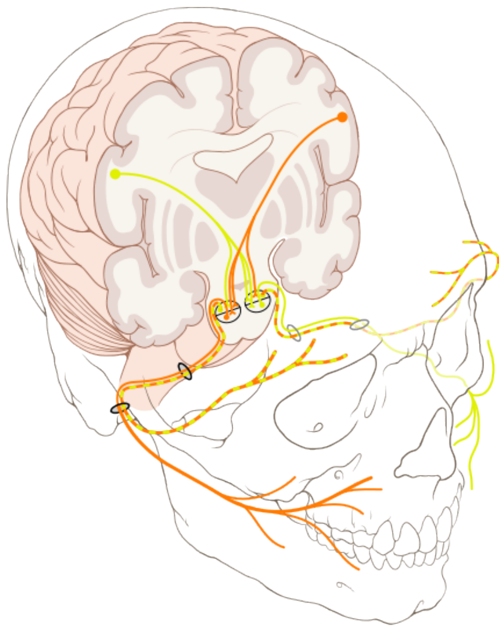


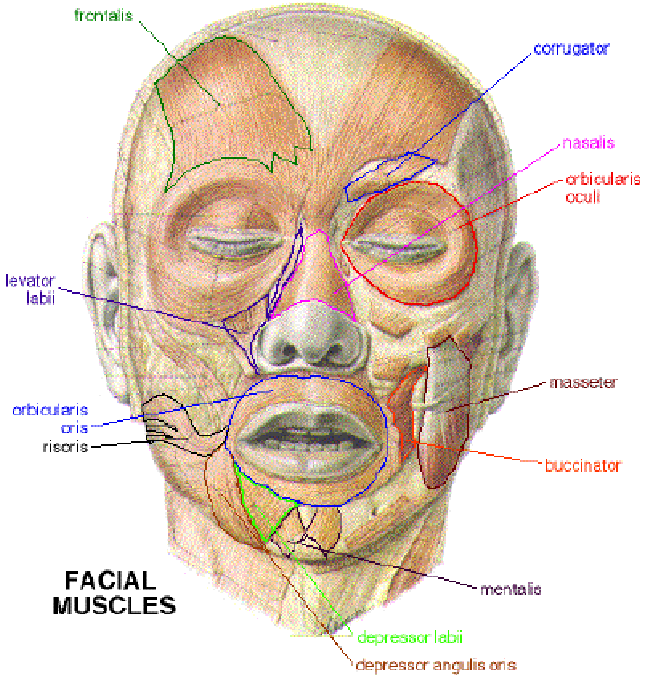
Our Aim

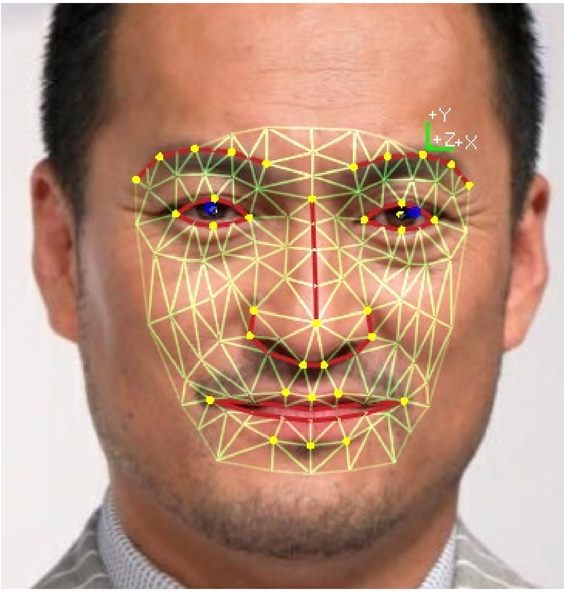
Address current challenges by:

- Developing a new pain assessment system (PainChek®)
- Leveraging from developments in use of Artificial Intelligence (AI)
- Using smart automation

INNATE HUMAN BEHAVIOR ARE EXPRESSED THROUGH FACIAL MUSCLES







BRAIN REACTION

- 20 – 40 ms

FACIAL MOVEMENTS

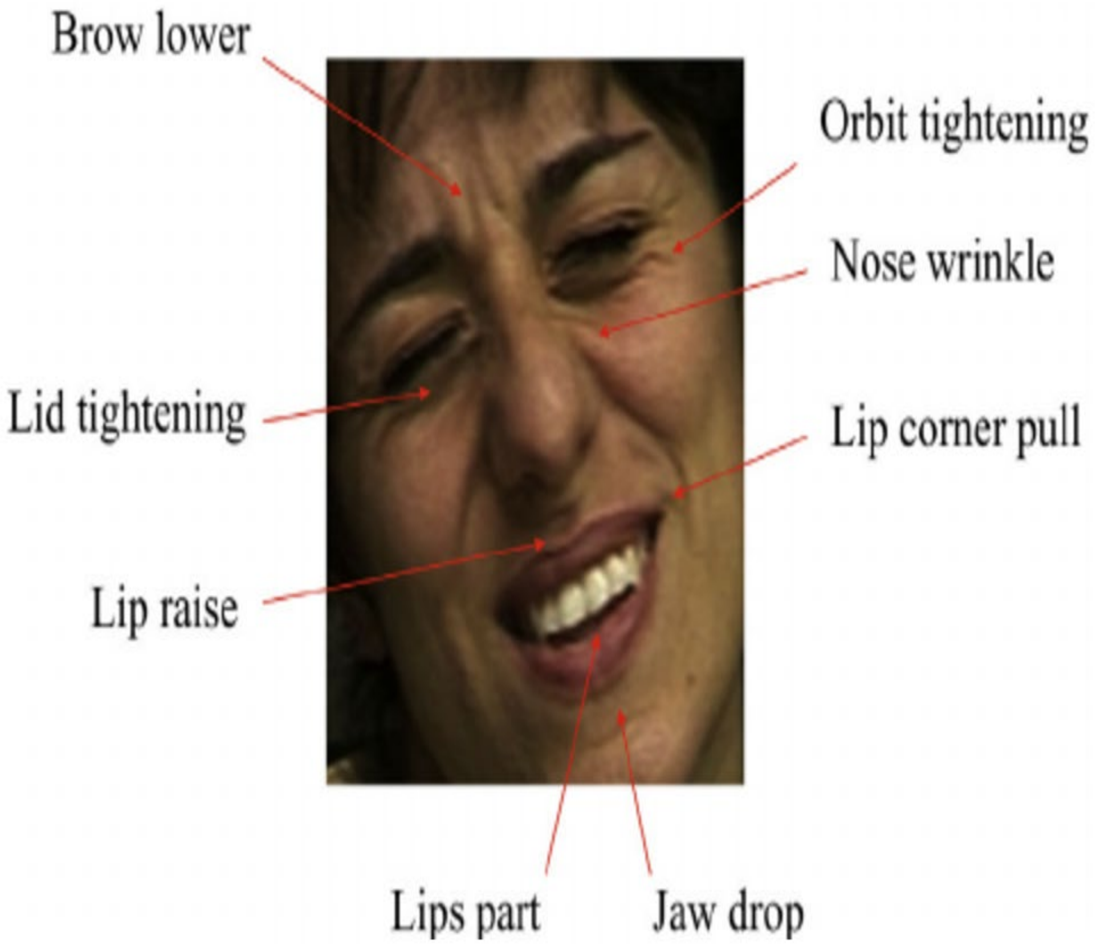
- 43 facial muscles

FACIAL TRACKING

- 68 or 170 points

Facial Action Coding System (FACS)

- Catalogue of facial expressions
- Used to describe changes, contraction, or relaxation of facial muscles
- Each facial muscle movement is described as Action Unit (AU)
- Combination of AUs produces facial expressions
  - e.g. Pain = AU 4 + AU 6/7 + AU 9/10 + AU43
- Limitations
  - Difficult
  - Time consuming
  - Laborious



What does the literature tells us?

- People with dementia lose their learnt pain behaviours
- Facial expression of pain is more intense in people with dementia
- Behavioural pain scales that have objective facial measures have better psychometric properties, than those containing vague facial descriptors

Effects of Alzheimer Disease on the Facial Expression of Pain

Paul A. Beach, PhD,† Jonathan T. Huck, BS,† Melodie M. Miranda, MD,‡ Kevin T. Foley, MD,§ and Andrea C. Bozoki, MD†‖*

Objectives: Facial expression may be a surrogate marker of pain in Alzheimer disease (AD) when self-report of pain is compromised. Recent studies have demonstrated increased pain sensitivity in AD; however, experimental pain studies analyzing facial expressions in AD are limited and report inconsistent results. The aims of this study were to examine facial expression of pain in AD patients and its relationship to sum-scored measures of multiple pain behavioral domains and subjective pain ratings.

Materials and Methods: The Facial Action Coding System (FACS) was used to characterize facial expressions in 35 AD patients and 33 healthy seniors during pressure algometry. To improve pain specificity, facial responses were categorized as pain-relevant or pain-irrelevant before group analyses. We also assessed the relationship of AD severity to differential facial responsiveness by correlating FACS-based results with clinical pain scales (portions of the Pain Assessment in Advanced Dementia scale and the Faces Pain Scale-Revised [FPS-R]).

Results: No significant relationship was found between AD severity and FACS scores. Pain-relevant, but not irrelevant, FACS scores were increased in AD patients compared with seniors without AD. Pain Assessment in Advanced Dementia scale stimulus-response slopes were correlated with those of pain-relevant FACS and FPS-R in both the groups. Pain-relevant FACS slopes showed no relationship with those of the FPS-R in either group.

Discussion: Pain sensitivity is increased across all severities of AD when measured using the FACS. Clinical observational pain scales support the relevance of facial expression as a partial compensatory pain communication modality for AD. However, measures of pain behavior that sum across objective coding of several domains provide a better indicator of subjective pain than measures of facial expression alone.

Keywords: Alzheimer disease, pain, Facial Action Coding System, Faces Pain Scale-Revised, Pain Assessment in Advanced Dementia scale

(*Clin J Pain* 2016;32:478–487)

There is increasing evidence that affective and cognitive dimensions of pain are altered in individuals with Alzheimer disease (AD).[1–5] Recent work suggests that in comparison with healthy seniors (HS) with intact cognition, individuals with AD may be more distressed by pain.[3–7] However, individuals with AD offer fewer pain symptoms, develop impaired comprehension of clinical pain scales, and demonstrate impaired pain vocabulary.[6,8,9] These factors increase the vulnerability to underdetection and undertreatment of pain and underscore the necessity to include nonverbal pain indicators, such as facial expressions, in clinical pain assessments.[10,11]

Several clinical observational pain scales use approximated or gestalt measures of facial response in determining whether an individual is exhibiting a "pained" expression.[12] Because of potential examiner bias inherent in this approach, the Facial Action Coding System (FACS)[13] has been suggested as a means to objectively quantify pain-related facial expressions in adults without dementia and with dementia.[14–19] Through the application of rigorous scoring criteria, the FACS fractionates facial expressions into discrete components (action units [AUs]) that can be coded in terms of frequency and intensity. Despite its potential to augment observational pain scales,[17,19–21] the tool has limited clinical utility as extensive rater training and time are required for its use. As a result of these limitations, the FACS has been used primarily in experimental contexts to examine pain-related facial response differences in individuals with AD and HS.[6,17,18] To our knowledge, an evaluation of the clinical relevance of FACS-based findings in the AD population has not been performed to date.

Pain response studies of individuals with dementia have found increased facial expressions compared with HS associated with painful activities such as venipuncture,[18] physical exercise in those with chronic musculoskeletal pain,[20] and experimental pain testing using mechanical pressure or electrical stimuli.[6,17,19] Several of these studies, including a seminal report by Kunz and colleagues,[1,16,18] evaluated mixed dementia groups,[6,20] so it is unclear whether the respective conclusions drawn can be extrapolated to the population of adults with probable AD. In studies enrolling AD patients exclusively, results have been inconsistent. For example, a study by Porter et al[18] found increased facial responsiveness during venipuncture in AD patients over a range of severity levels compared with HS. A more recent study by Lints Martindale et al[19] found no facial response differences between mild to moderate AD (mAD) patients related to mechanical pressure and electrical pain stimuli in comparison to HS participants. Of note, only Kunz and colleagues differentiated between pain-relevant and pain-irrelevant facial expressions.

Although some investigators have hypothesized that individuals with advanced AD exhibit fewer pain behaviors than those with milder AD,[22–24] very few experimental studies have included severe AD (sAD) patients. A previous study conducted by the authors[7] involving patients with mild to advanced AD demonstrated that overall pain responsiveness (as measured by portions of the Pain

Received for publication May 1, 2015; revised November 5, 2015; accepted September 8, 2015.
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Supported by the MSU Department of Family Medicine Pearl Aldrich Graduate Student Fellowship, East Lansing, MI, (Grant: RT083166-F5015) and the Blue Cross Blue Shield of Michigan Foundation, Detroit, MI, (Grant: 1981.SAP). The authors declare no conflict of interest.
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DOI: 10.1097/AJP.0000000000000302

Facial pain expression

Pain Manage 2011; 1(4):386-397

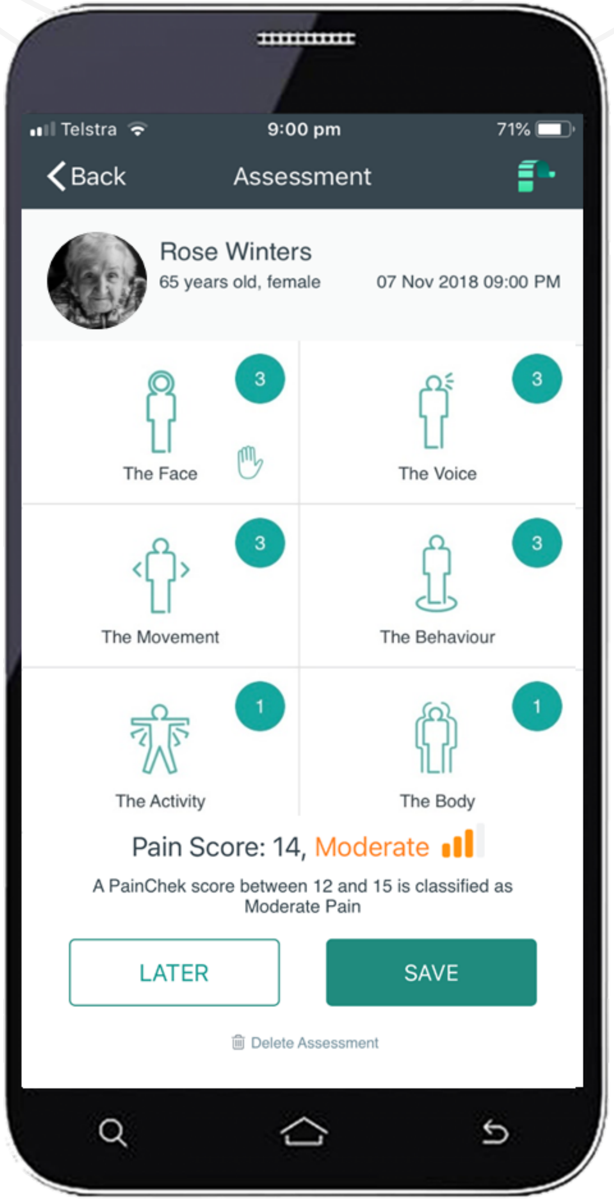
Kenneth M Prkachin†

Practice Points

- People in pain from various causes often show a characteristic facial expression.
- The expression consists mainly of eye closure, brow lowering, contraction of the levator labii muscle and, especially, contraction of the orbicularis oculi, narrowing the eye opening and raising the cheeks.
- The expression encodes pain intensity, but is not inevitable.
- Observers of the pain expression typically underestimate the intensity of pain that it conveys: it should be thought of as a 'late' signal – if it is there it is more intense than you may think.
- High levels of exposure to facial expressions of pain appear to bias observers against perceiving pain. This may explain why some healthcare professionals show an exaggerated underestimation bias.
- The clinical implications of pain underestimation are not known and should be the focus of increased attention and research.

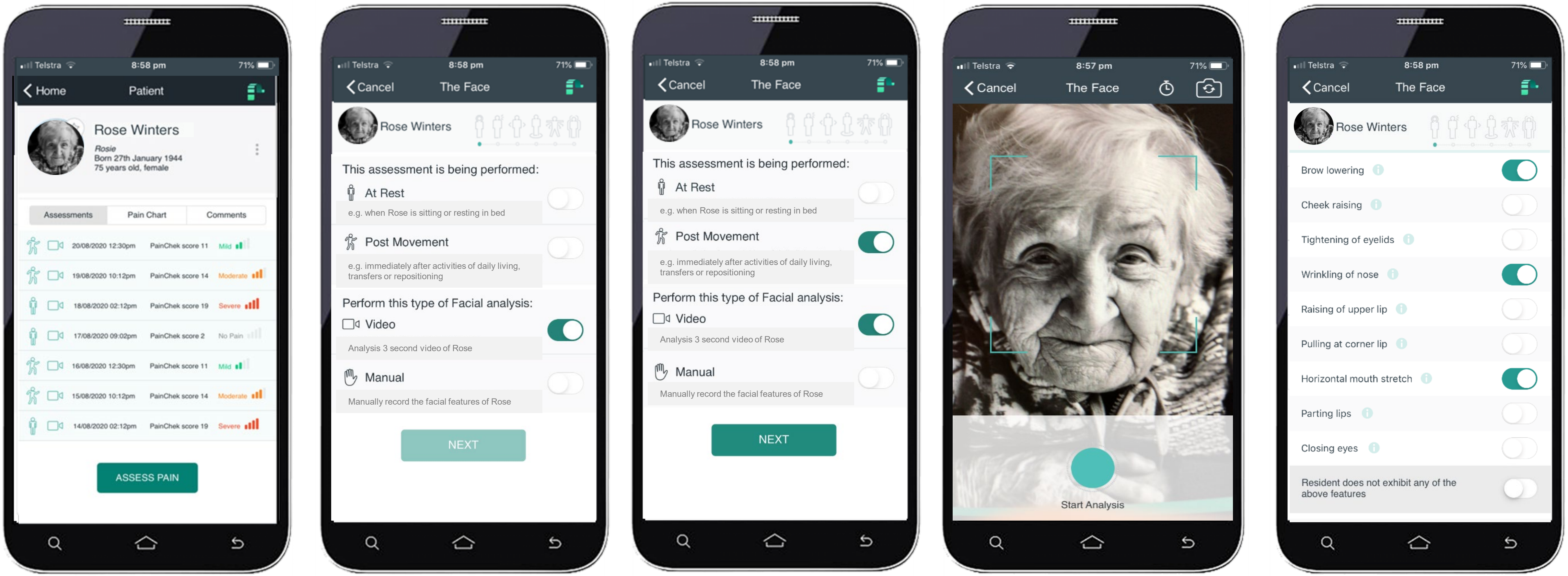
PainChek®

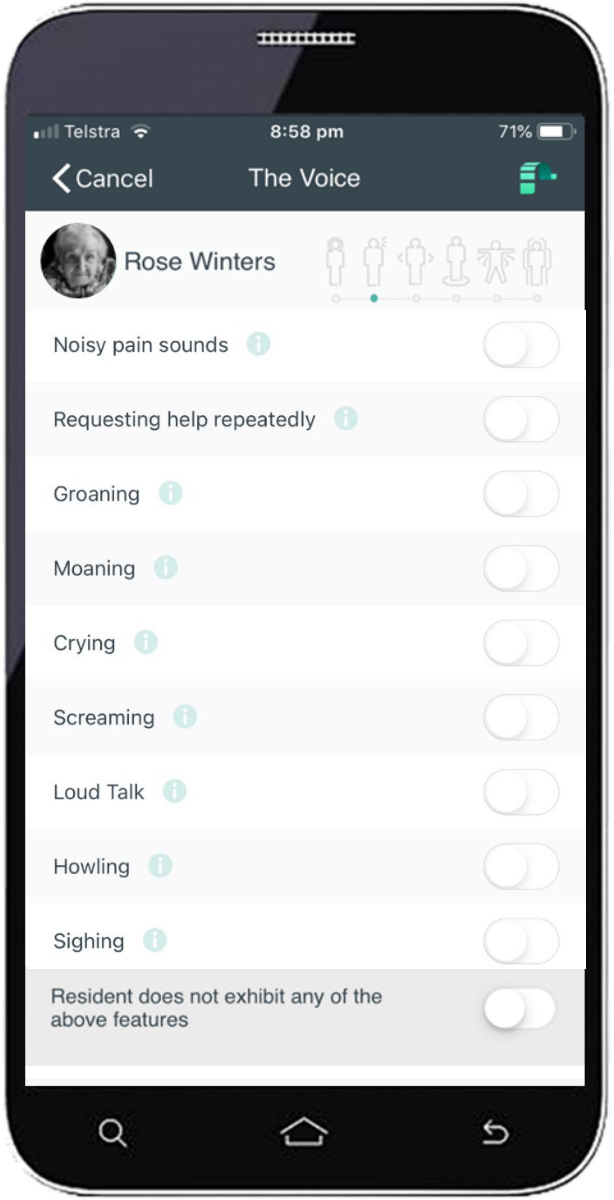
- **42** items
  - Communicative, protective and subtle pain cues
- **6** domains
  - Domain 1: **Face** Domain
    - Based on Ekman's Facial Action Code System (FACS), 1978
  - Domain 2-6: **Voice**, **Movement**, **Behaviour**, **Activity**, **Body**
    - American Geriatric Society Indicators of Persistent Pain (AGS, 2002)
- Binary Scoring
  - Yes/No

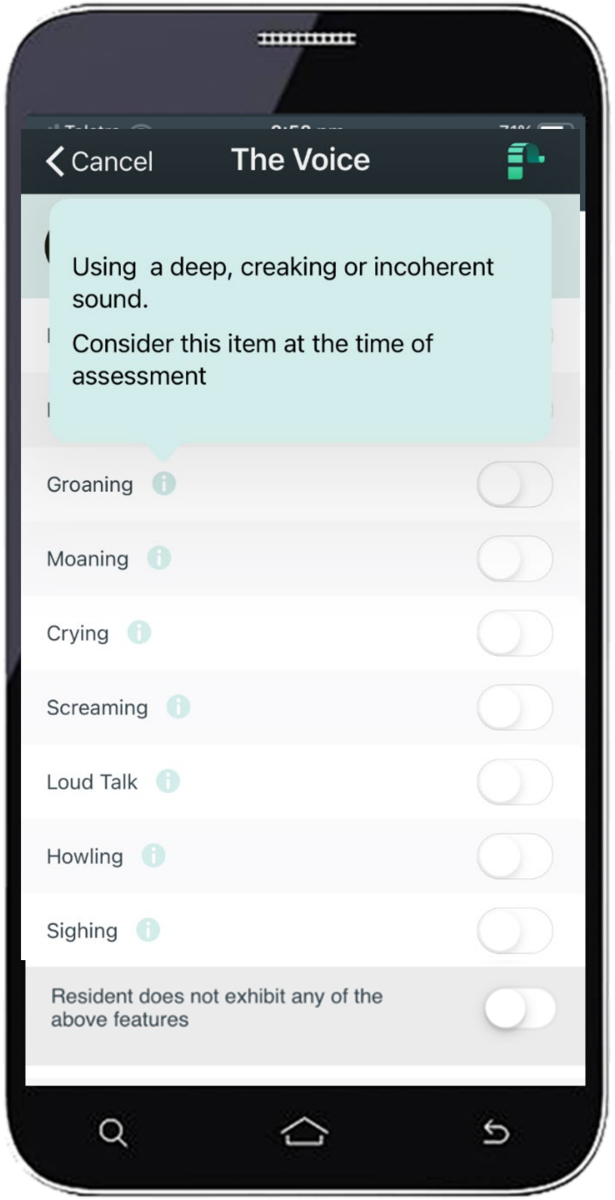


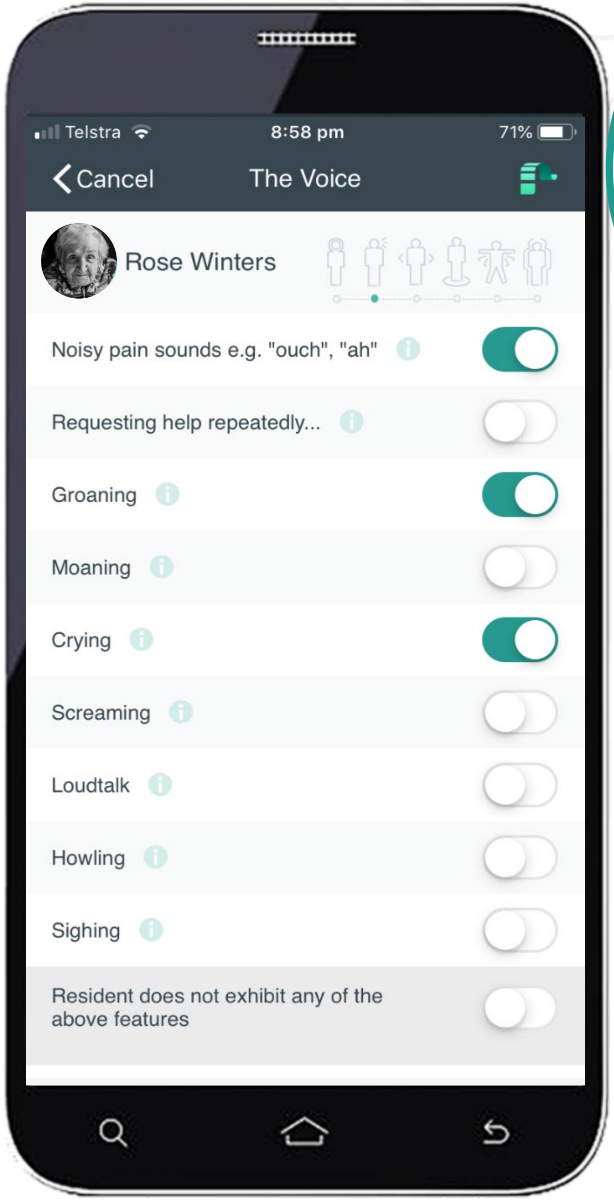
Automated Facial Analysis

Step 1.



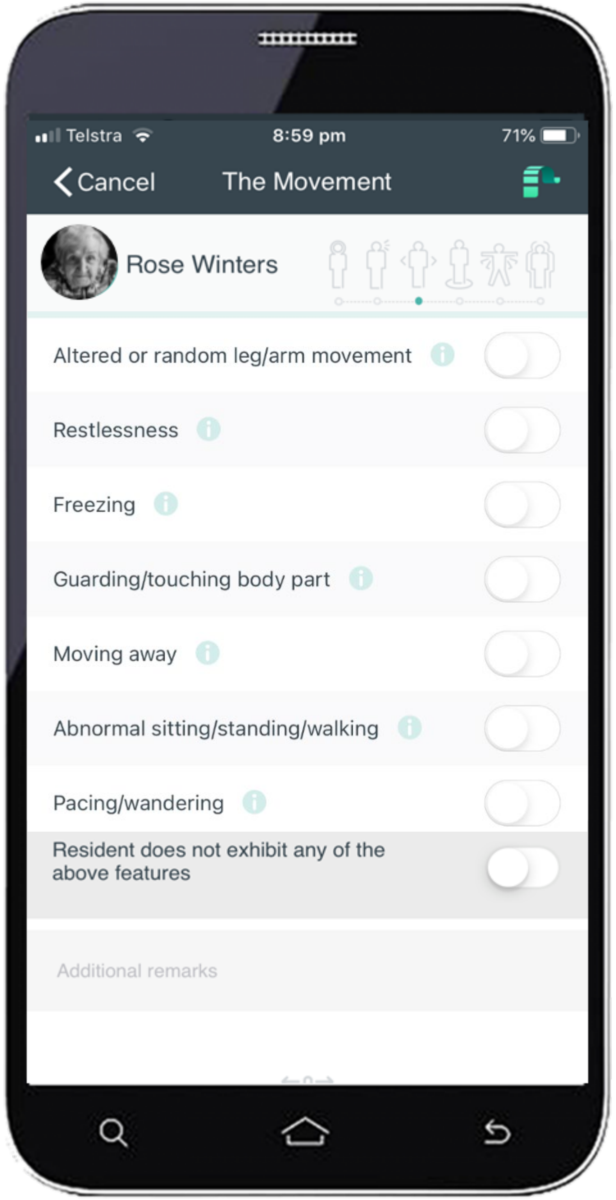


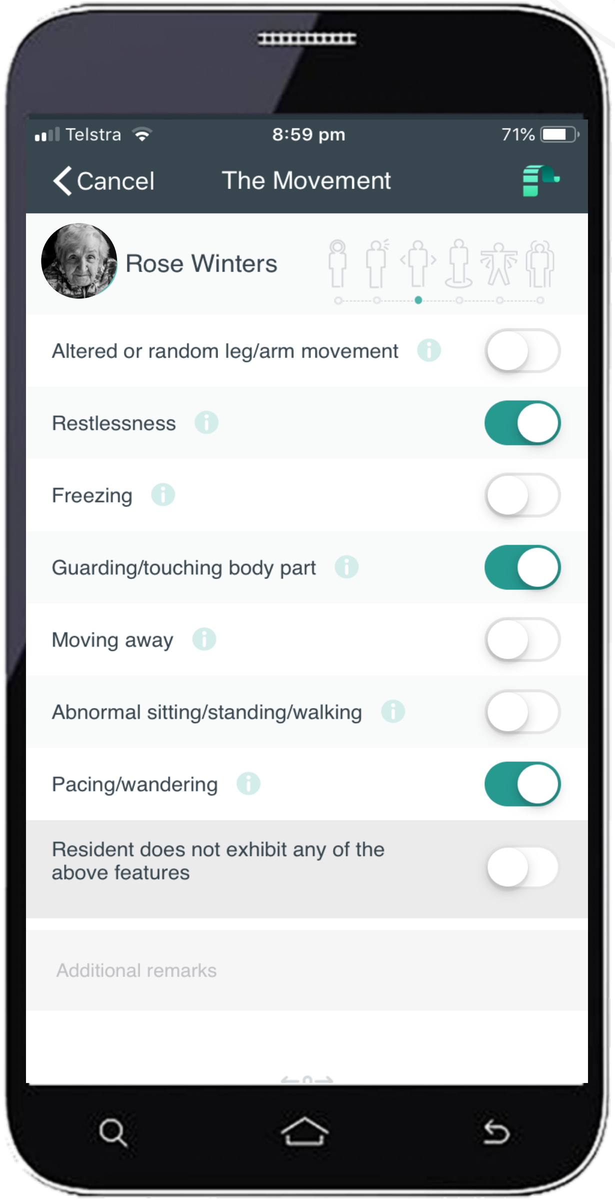




Step 2.

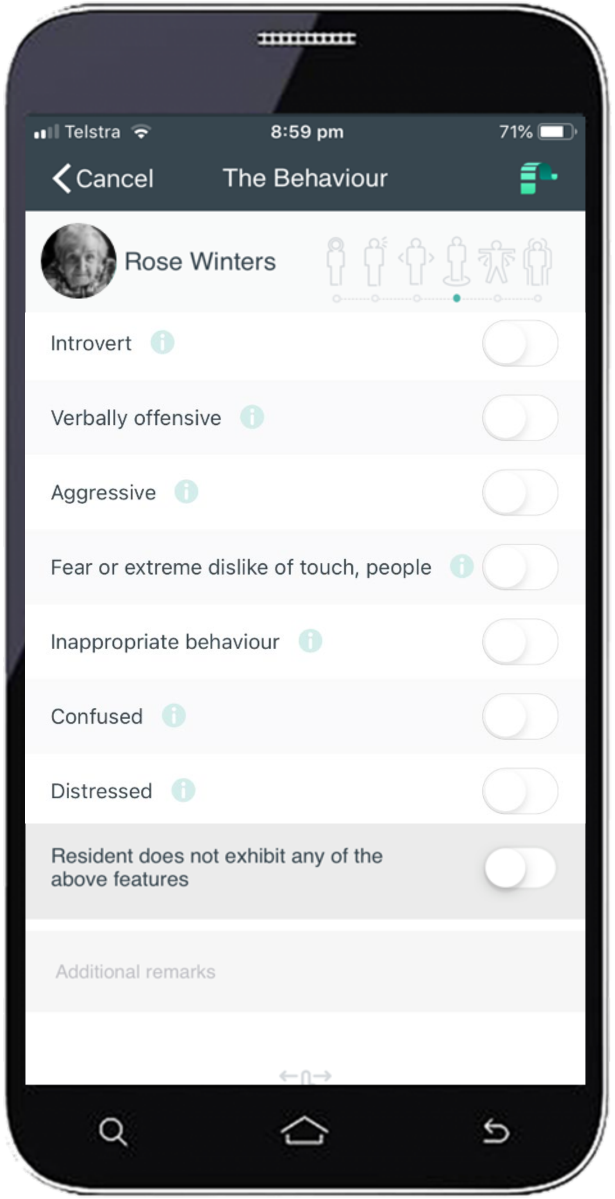
Select all items observed

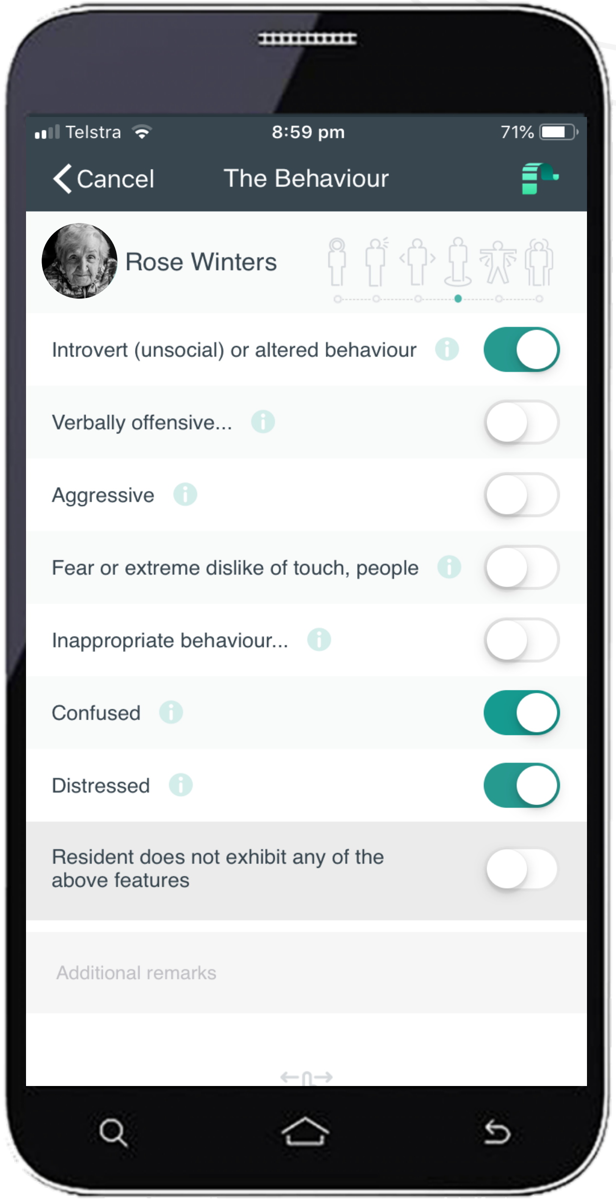




Step 3.

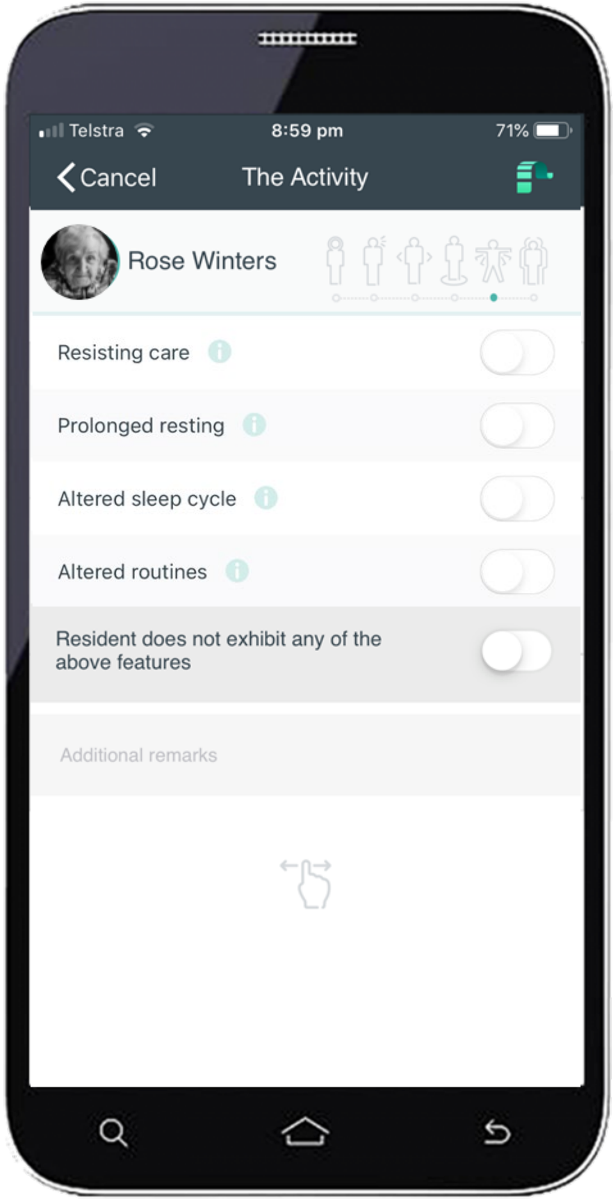
Select all items observed

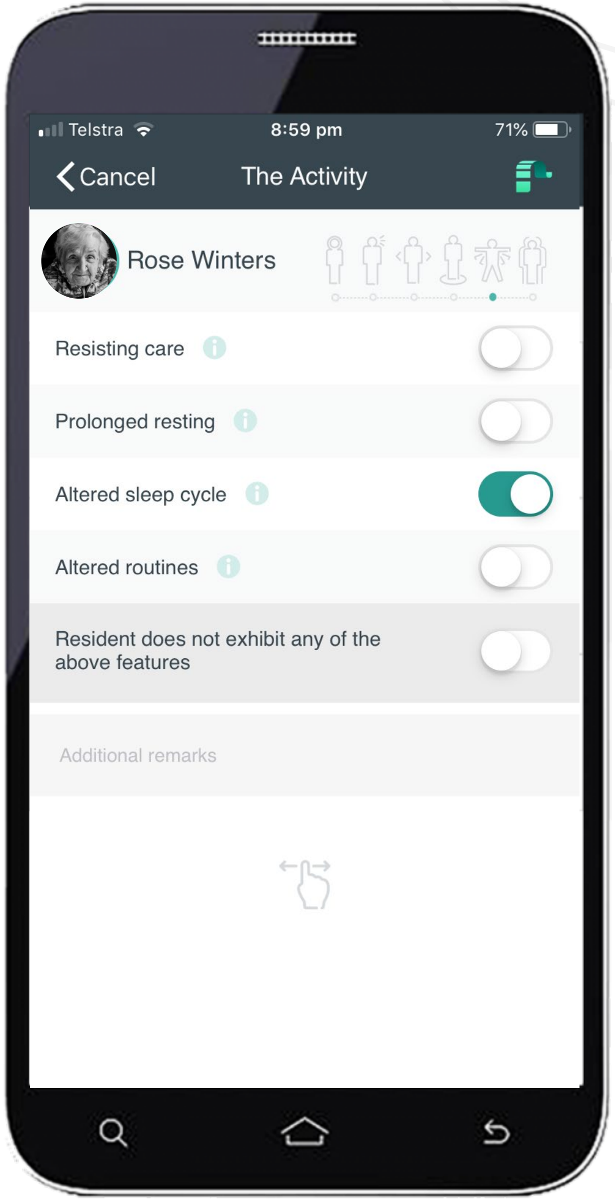




Step 4.

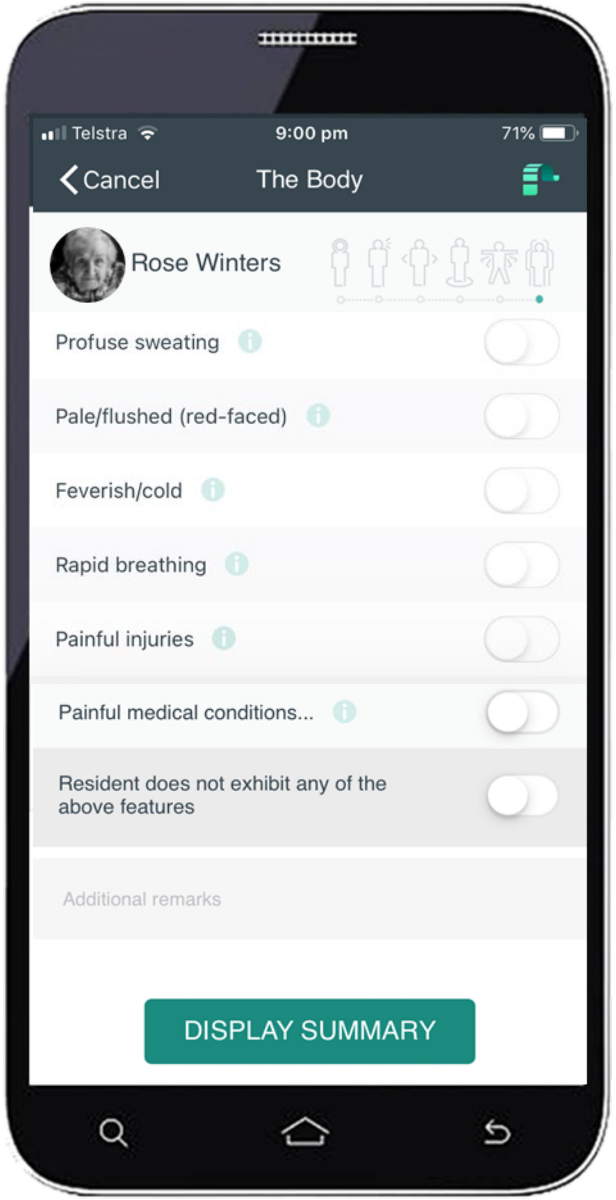
Select all items observed

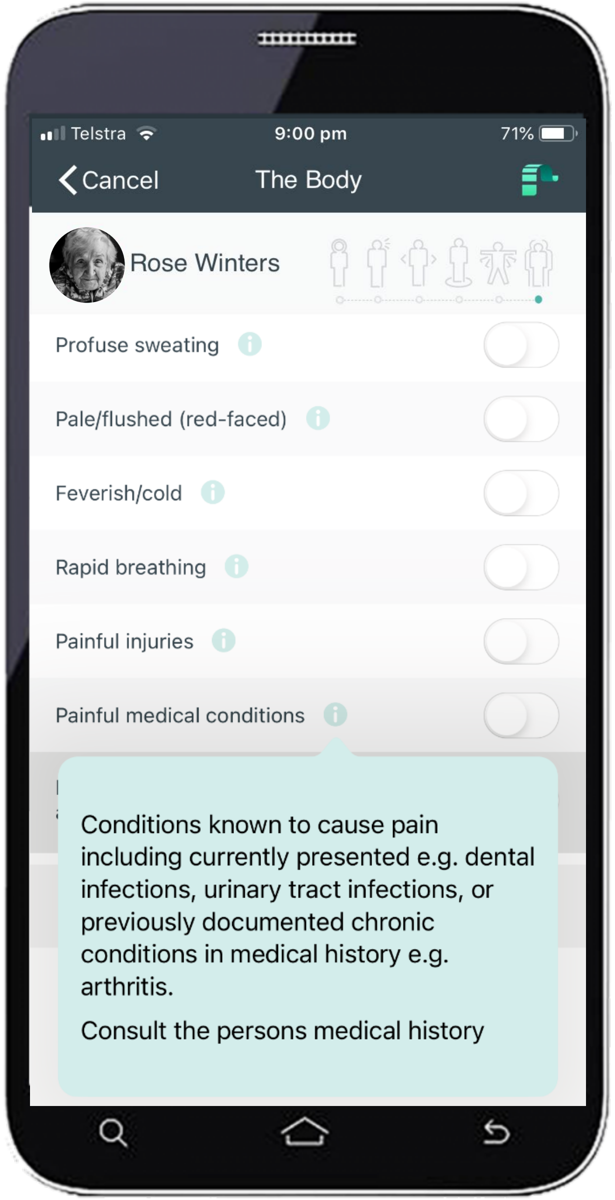


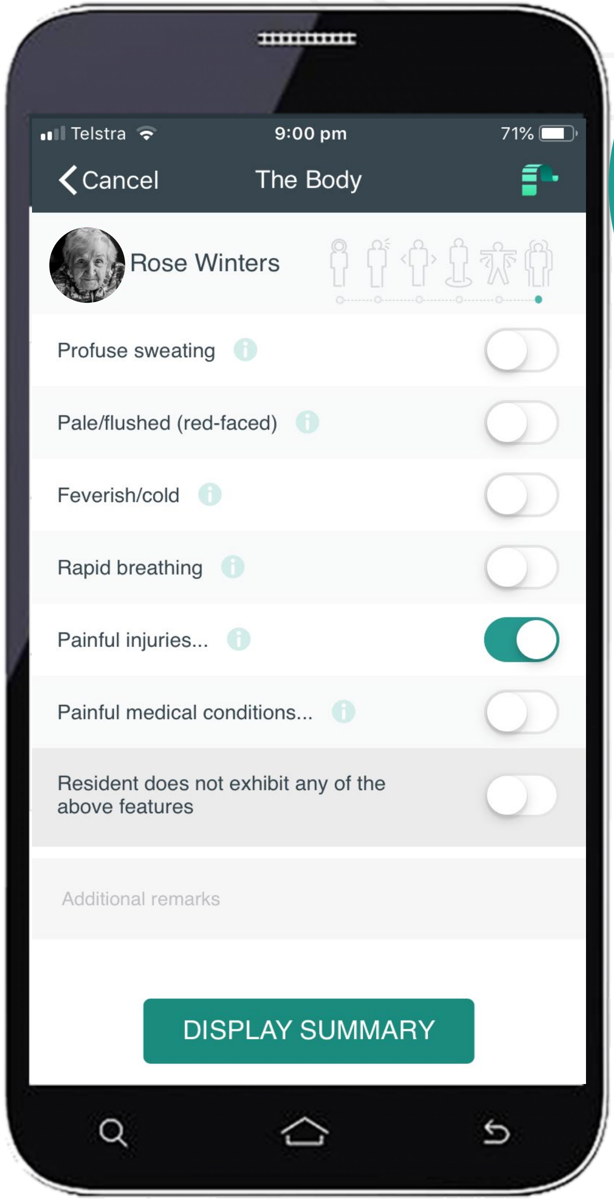


Step 5.

Select all items observed or documented







Step 6.

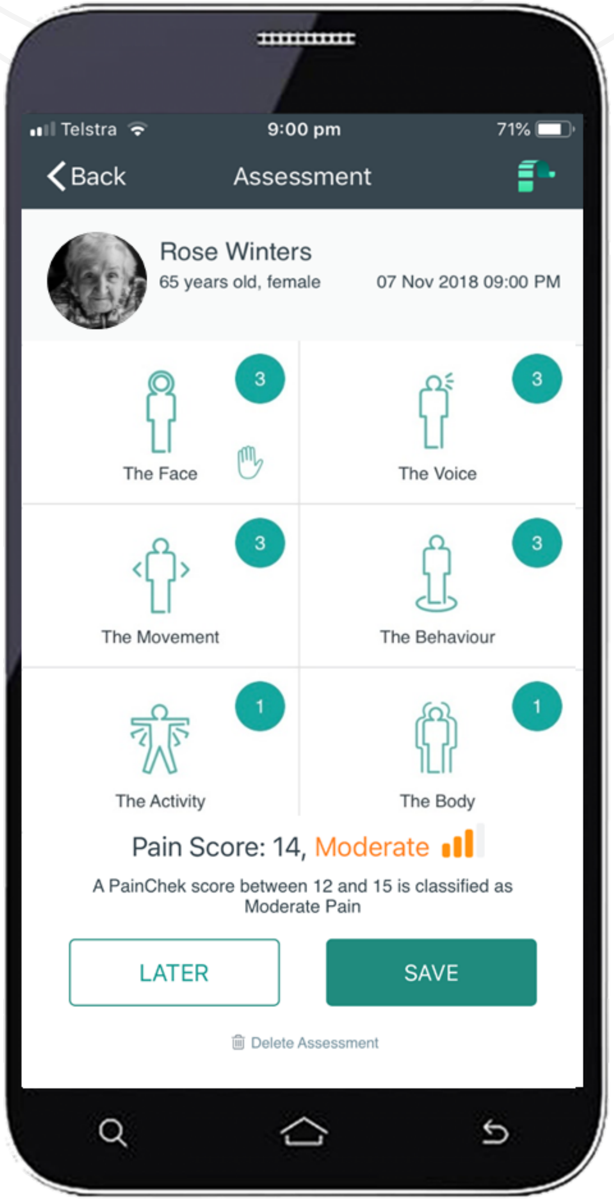
Select all items observed or documented

Assessment Complete

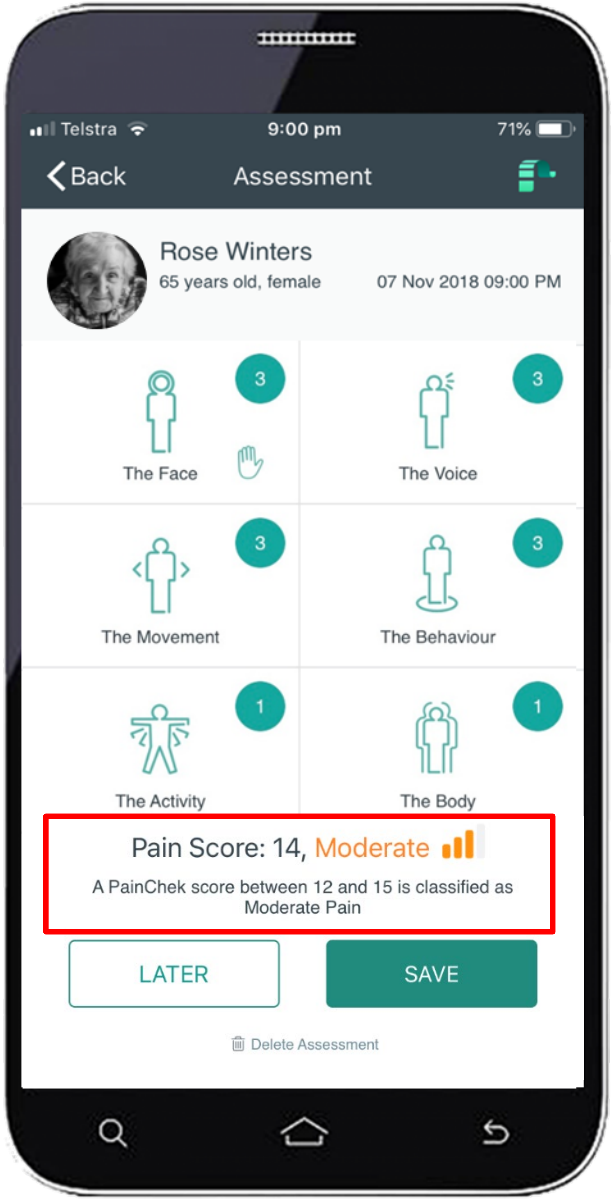
- Automated scoring
  - Final score= total domain scores

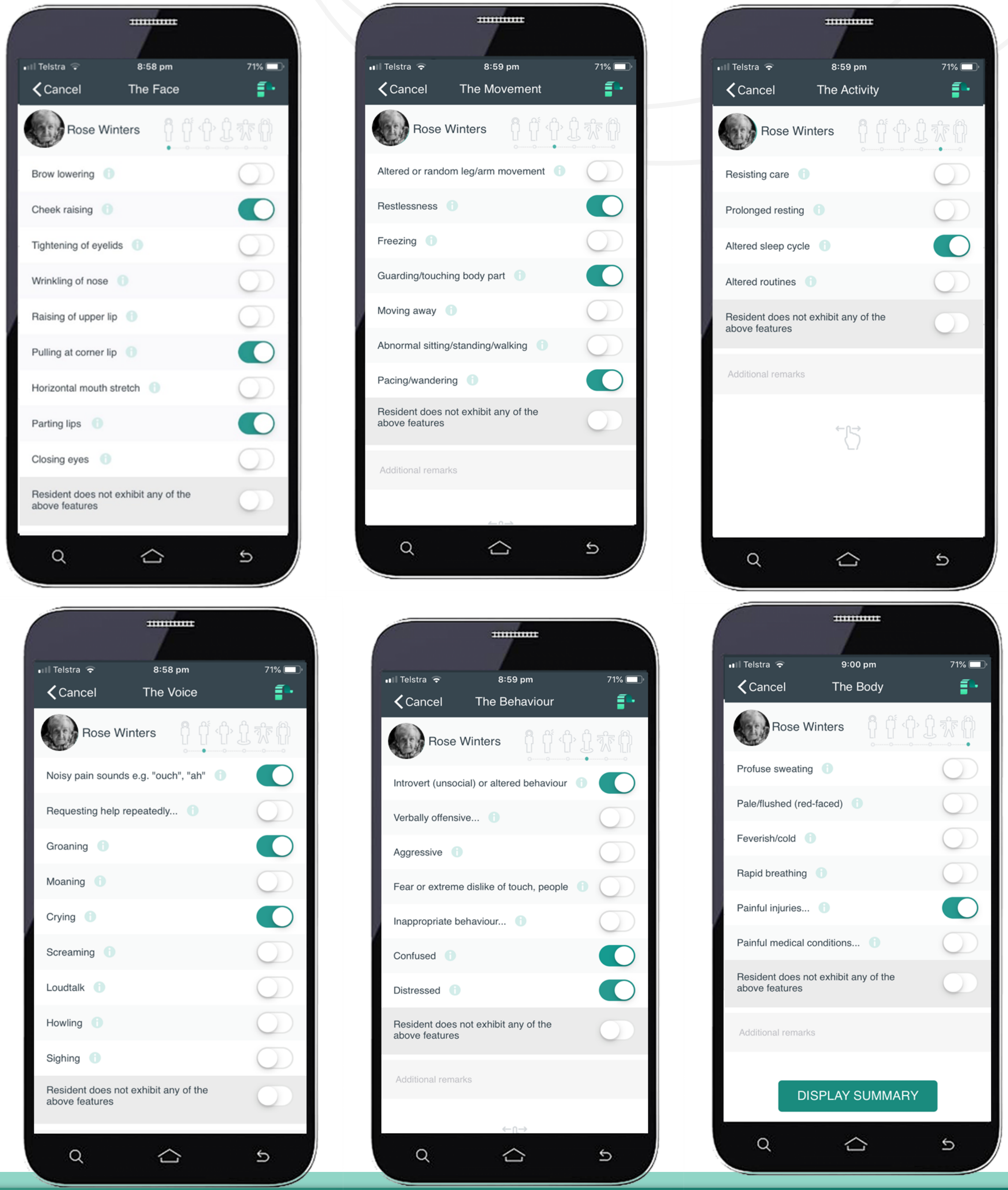
- Numerical value indicates pain intensity
  - No pain: 0-6
  - Mild pain: 7-11
  - Moderate pain: 12-15
  - Severe pain: 16-42

- Pain intensity groups are comparable to Abbey Pain Scale scoring

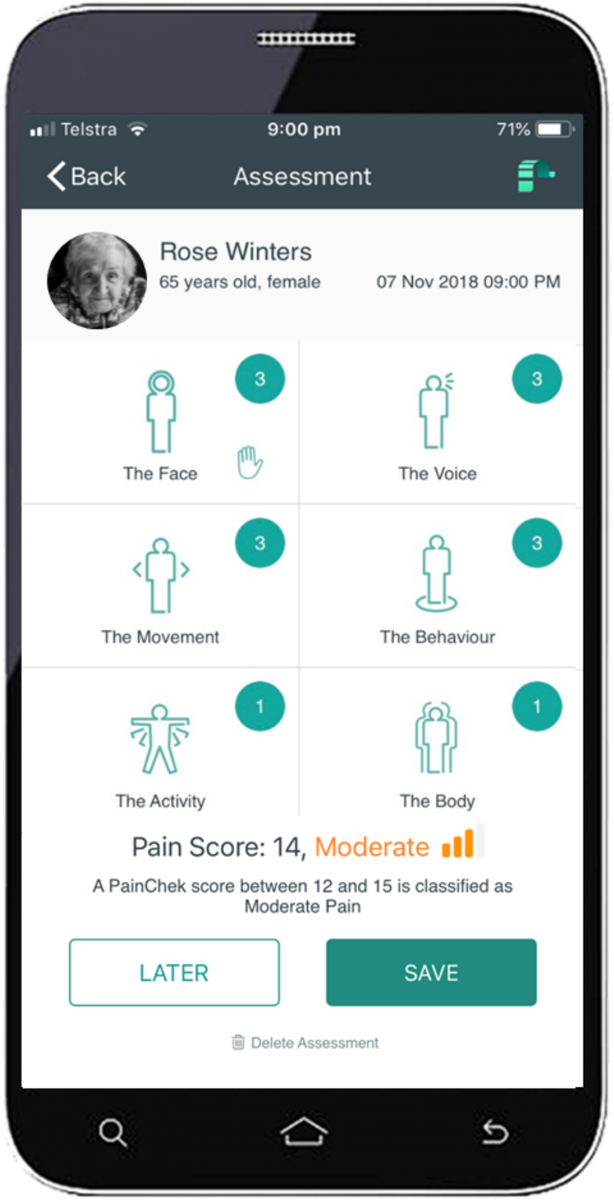


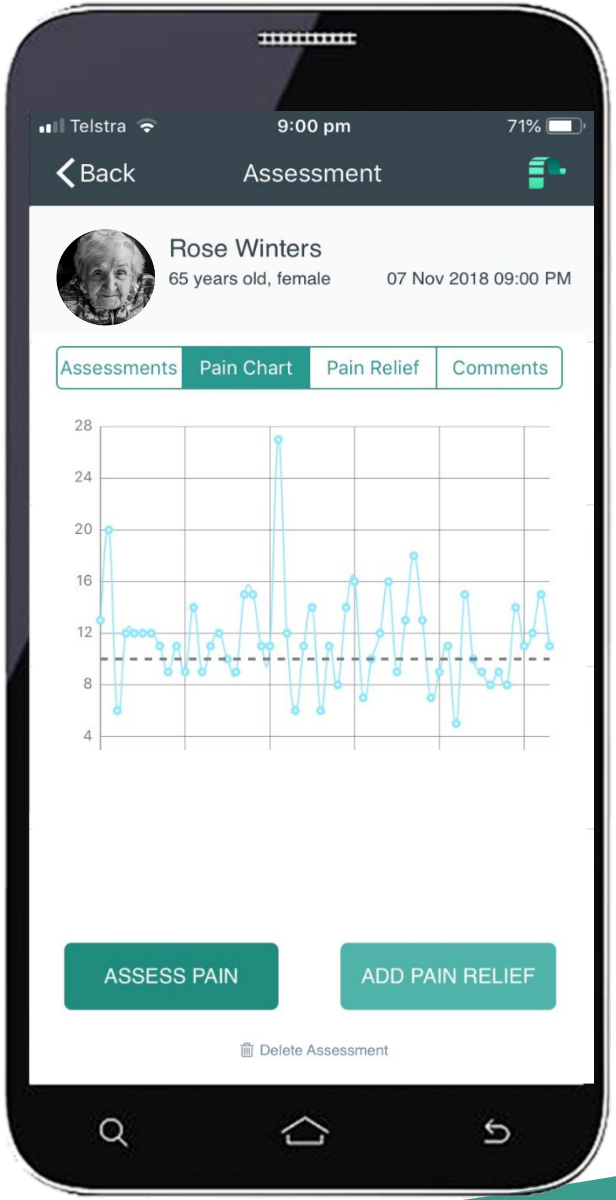
Pain Profile



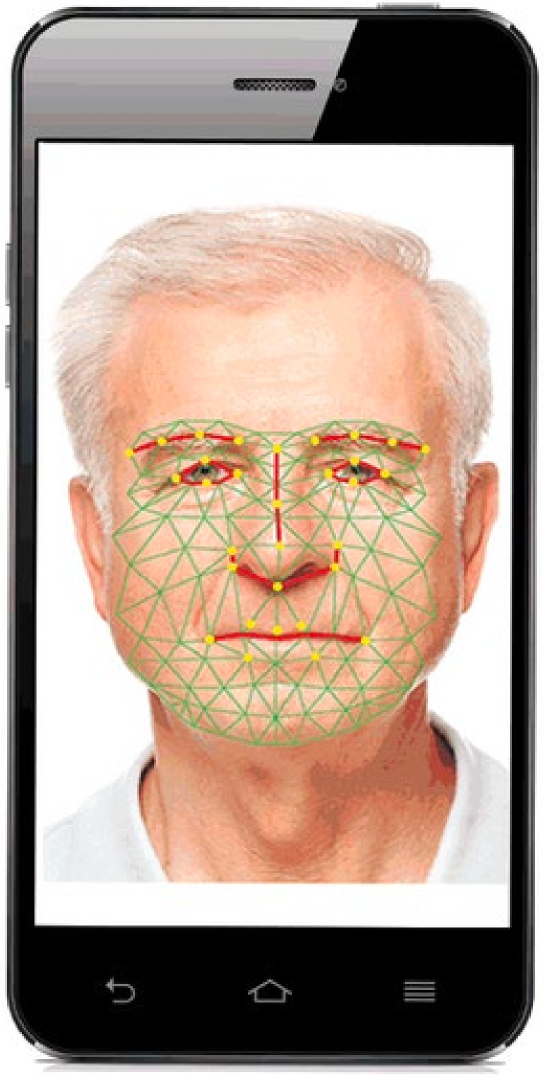


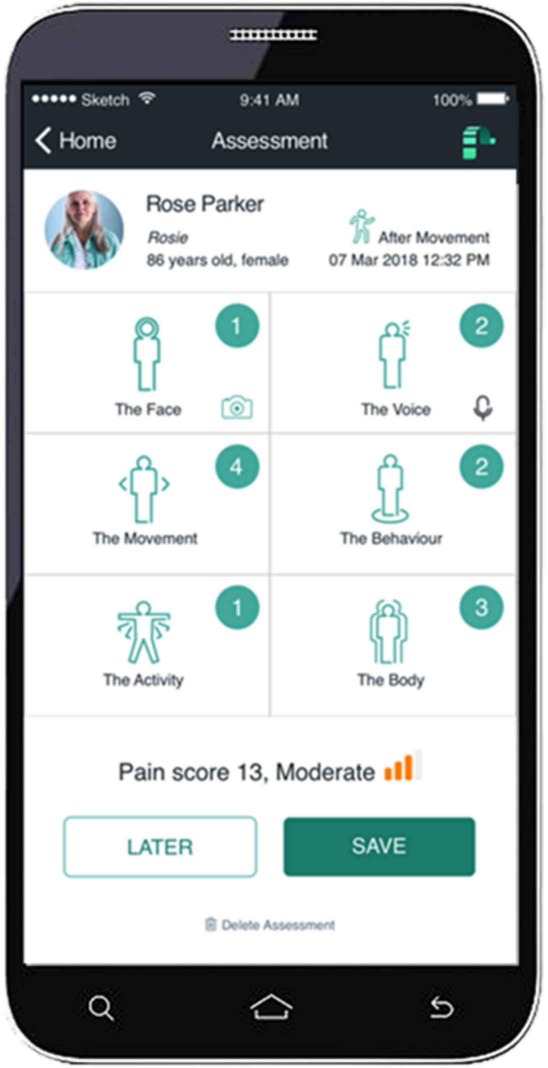
Monitoring Pain





View automated reports and pain trends within the app

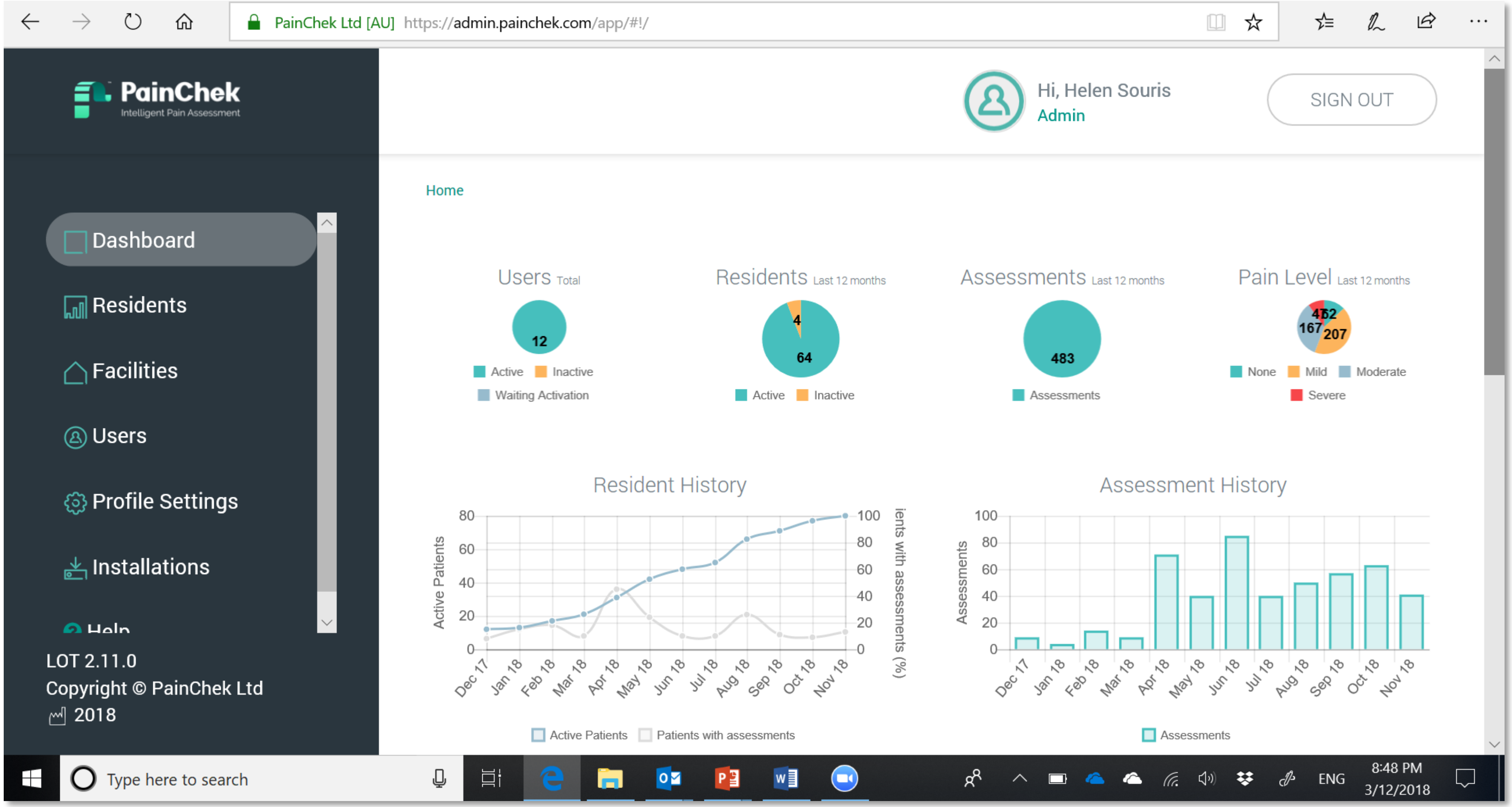




- iOS & Android
- Web Admin Portal
- Open API
- Training & support

PainChek® application and pain assessment domains

Access reports via Web Admin Portal*

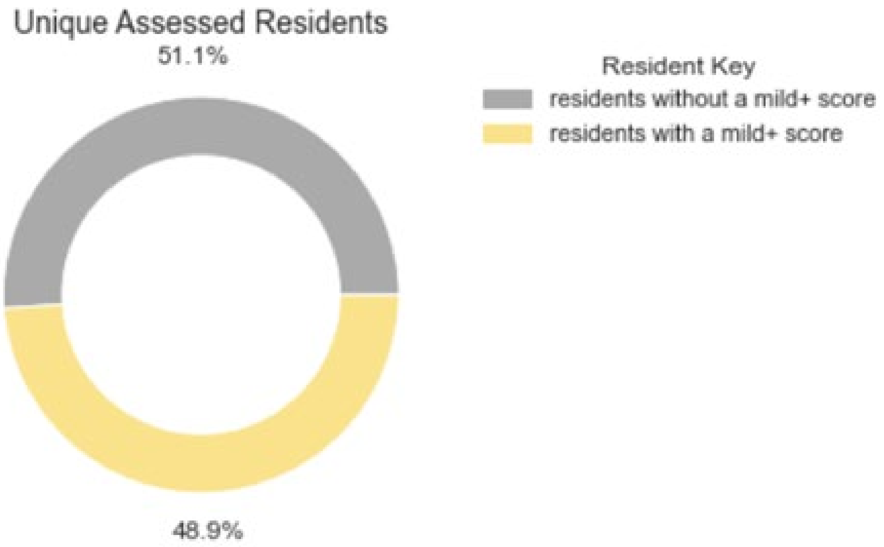


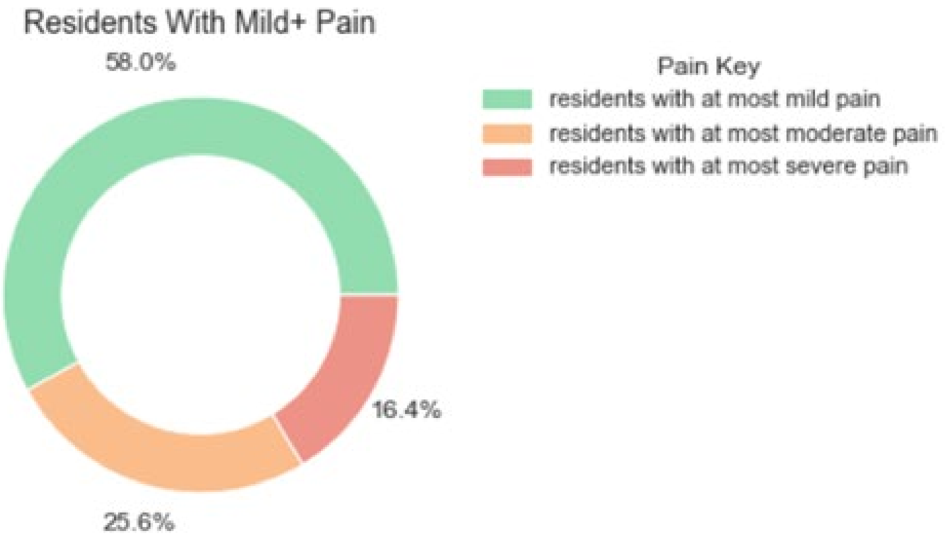
* Enterprise license only

Data Analytics to Drive Best Practice

Looking at **508176** total assessments, across **19694** assessed residents from **565** facilities in RAC

- *65.3%* female residents, *34.6%* male residents
- median age: *87*

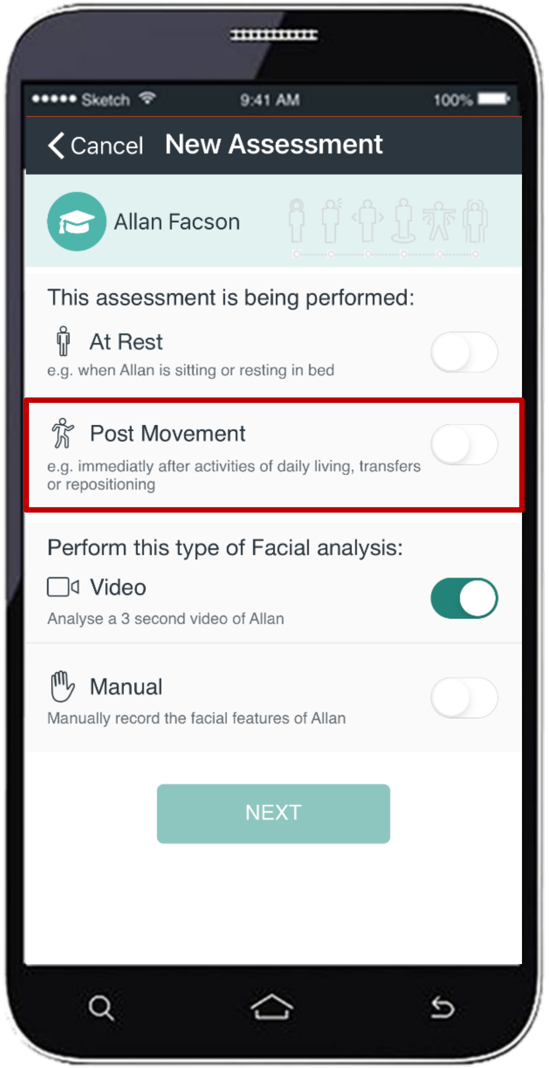




Data Analytics to Drive Best Practice

Key Practice Points

- It is imperative to maximize self-report of pain and to gather understanding of the total pain experience directly from patients.
- Two emerging self-report practices are the routine (1) assessment of the impact of pain on function and (2) measurement of pain during movement-based activities.
- Movement-based pain assessment is the assessment of pain intensity and interference on function during movement or physical activities in patients.
- Consistent implementation of the practice of movement-based pain assessment will require development of regulatory and organizational policies and procedures to support the nursing and healthcare practices.



Booker SQ, Herr KA, Horgas AL. A paradigm shift for movement-based pain assessment in older adults: Practice, policy and regulatory drivers. *Pain Management Nursing*. 2021;22:21-27

Data Analytics to Drive Best Practice

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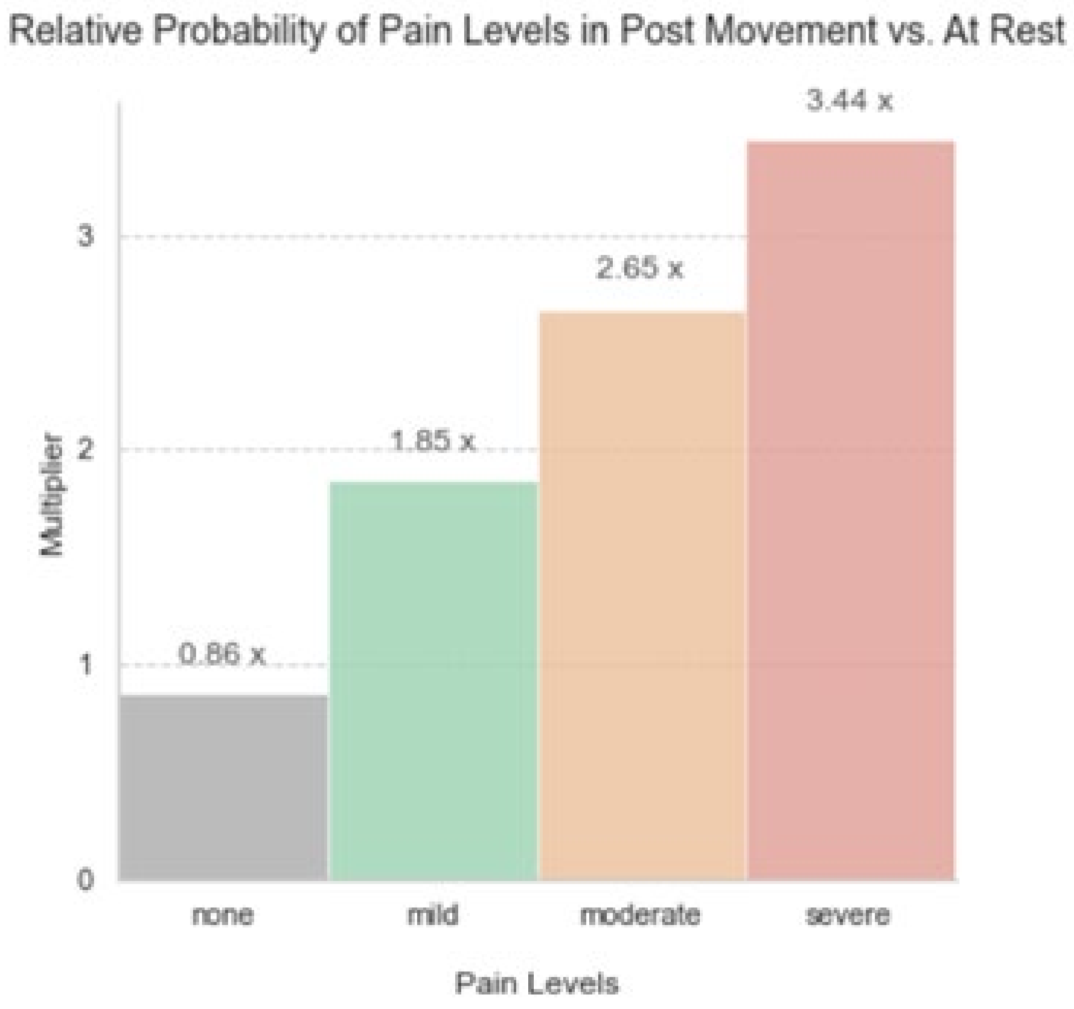


Booker SQ, Herr KA, Horgas AL. A paradigm shift for movement-based pain assessment in older adults: Practice, policy and regulatory drivers. *Pain Management Nursing*. 2021;22:21-27

The PainChek® History

2012

Idea conceived by Hughes, Hoti, Atee

2012

Concept initially supported by Alzheimer’s Australia

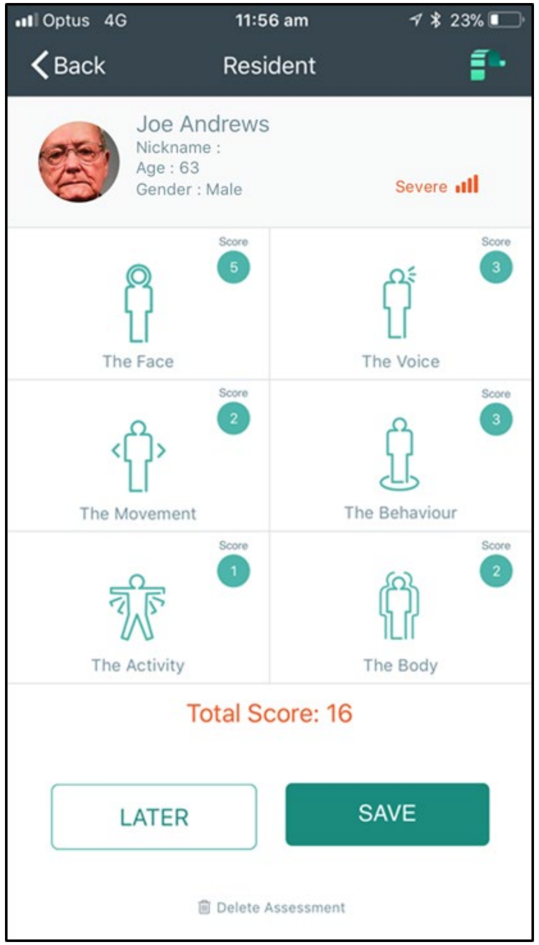
2013

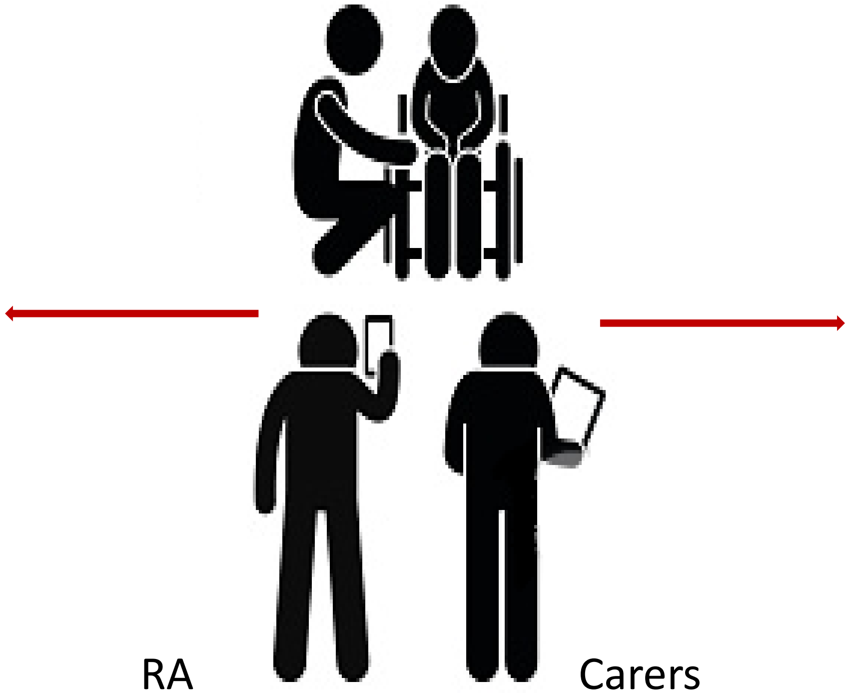
Engaged with NVISO, specialized in facial recognition & analysis

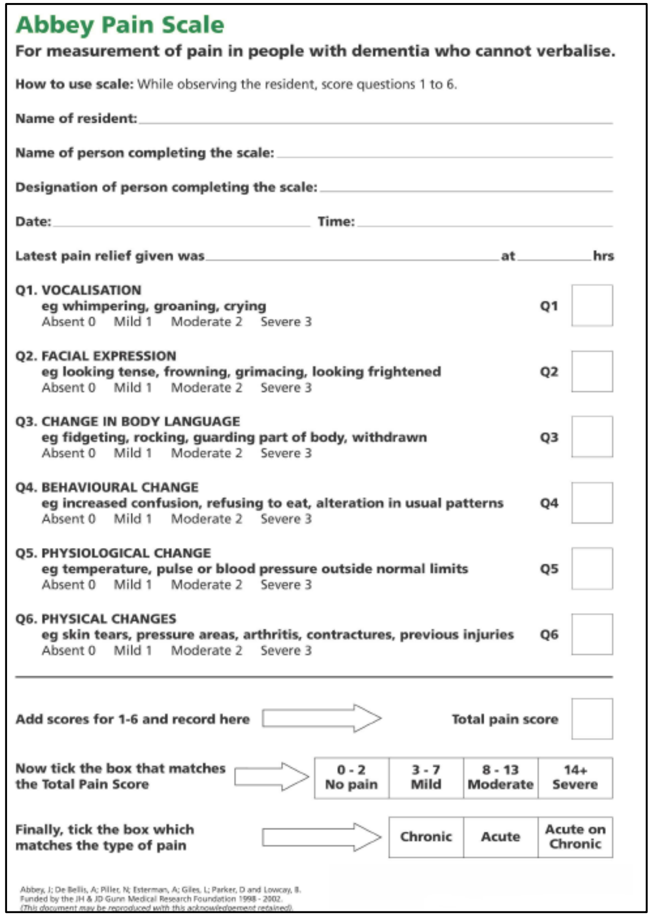
2013

First prototype released in November

Clinical Studies







Abbey Pain Scale

For measurement of pain in people with dementia who cannot verbalise.

How to use scale: While observing the resident, score questions 1 to 6.

Name of resident: ______

Name of person completing the scale: ______

Designation of person completing the scale: ______

Date: ______ **Time:** ______

Latest pain relief given was ______ **at** ______ **hrs**

Q1. VOCALISATION
eg whimpering, groaning, crying
Absent 0 Mild 1 Moderate 2 Severe 3 — **Q1** ☐

Q2. FACIAL EXPRESSION
eg looking tense, frowning, grimacing, looking frightened
Absent 0 Mild 1 Moderate 2 Severe 3 — **Q2** ☐

Q3. CHANGE IN BODY LANGUAGE
eg fidgeting, rocking, guarding part of body, withdrawn
Absent 0 Mild 1 Moderate 2 Severe 3 — **Q3** ☐

Q4. BEHAVIOURAL CHANGE
eg increased confusion, refusing to eat, alteration in usual patterns
Absent 0 Mild 1 Moderate 2 Severe 3 — **Q4** ☐

Q5. PHYSIOLOGICAL CHANGE
eg temperature, pulse or blood pressure outside normal limits
Absent 0 Mild 1 Moderate 2 Severe 3 — **Q5** ☐

Q6. PHYSICAL CHANGES
eg skin tears, pressure areas, arthritis, contractures, previous injuries
Absent 0 Mild 1 Moderate 2 Severe 3 — **Q6** ☐

Add scores for 1-6 and record here → **Total pain score** ☐

Now tick the box that matches the Total Pain Score →

0 - 2 No pain	3 - 7 Mild	8 - 13 Moderate	14+ Severe

Finally, tick the box which matches the type of pain →

Chronic	Acute	Acute on Chronic

Abbey, J; De Bellis, A; Piller, N; Esterman, A; Giles, L; Parker, D and Lowcay, B.
Funded by the JH & JD Gunn Medical Research Foundation 1998 - 2002.
(This document may be reproduced with this acknowledgement retained).

- Blinded assessments
- Part of routine care: At rest and with movement
- Care workers assisted with answering some questions about residents’ behaviours e.g. sleeping/eating pattern

PainChek

The PainChek® Story: Proven validity, reliability and accuracy

Atee M, Hoti K, Parsons R, Hughes J. A novel pain assessment tool incorporating automated facial analysis: interrater reliability in advanced dementia. ***Clinical Interventions in Aging*****.** 2018;13: 1245-1258

Hoti K, Atee M, Hughes J. Clinimetric properties of the electronic Pain Assessment Tool (ePAT) for aged-care residents with moderate to severe dementia. ***Journal of Pain Research***. 2018;11: 1037–1044

Atee M, Hoti K, Hughes J. Psychometric Evaluation of the Electronic Pain Assessment Tool: An Innovative Instrument for Individuals with Moderate-to-Severe Dementia. ***Dementia and Geriatric Cognitive Disorders***. 2017;44:256–267

Atee M, Hoti K, Hughes J. Pain Assessment in Dementia: Evaluation of a Point-of-Care Technological Solution. ***Journal of Alzheimer's Disease.*** 2017; 60: 137-150

Dementia and Geriatric Cognitive Disorders

Dement Geriatr Cogn Disord
DOI: 10.1159/000485377
Accepted: November 15, 2017
Published online: [redacted]

Original Research Article

Psychometric Evaluation of the Electronic Pain Assessment Tool: An Innovative Instrument for Individuals with Moderate-to-Severe Dementia

Mustafa Atee[a] Kreshnik Hoti[a, b] Jeffery D. Hughes[a]

[a] School of Pharmacy, Faculty of Health Sciences, Curtin University, Bentley, WA, Australia;
[b] Division of Pharmacy, Faculty of Medicine, University of Pristina, Pristina, Kosovo

- **Design:** Observational study ePAT vs Abbey Pain Scale
- **Location:** 2 residential aged care facilities
- **Participants:** 34 residents with moderate to severe dementia
- **Pain Assessments:** Total, n = 400 (At rest, n = 204; After movement, n = 196)

Validity

	Number of paired pain assessments, *n* (%)	Pearson's correlation, *r*
Rest	204 (51)	0.896
Movement	196 (49)	0.904
Overall	400 (100)	0.911

ePAT, electronic Pain Assessment Tool; APS, Abbey Pain Scale. All correlation values are significant at the 0.01 level (2-tailed).

Inter-rater Reliability
Overall agreement on the categorical pain scores was excellent (κ_w = 0.857; 95% CI: 0.819–0.895).

Greater agreement among raters was found during rest (κ = 0.840; p = 0.000) compared to movement (κ = 0.772; p = 0.000).

Journal of Pain Research

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ORIGINAL RESEARCH

Clinimetric properties of the electronic Pain Assessment Tool (ePAT) for aged-care residents with moderate to severe dementia

This article was published in the following Dove Press journal:
Journal of Pain Research

Kreshnik Hoti[1,2]
Mustafa Atee[1]
Jeffery D Hughes[1]

[1]School of Pharmacy, Curtin University, Perth, Australia; [2]Division of Pharmacy, Faculty of Medicine, University of Prishtina, Pristina, Kosovo

Purpose: Accurate pain assessment is critical to detect pain and facilitate effective pain management in dementia patients. The electronic Pain Assessment Tool (ePAT) is a point-of-care solution that uses automated facial analysis in conjunction with other clinical indicators to evaluate the presence and intensity of pain in patients with dementia. This study aimed to examine clinimetric properties (clinical utility and predictive validity) of the ePAT in this population group.
Methods: Data were extracted from a prospective validation (observational) study of the ePAT in dementia patients who were ≥65 years of age, living in a facility for ≥3 months, and had

Journal of Pain Research 2018:11 1037–1044

Clinimetric Properties

Table 4 Calculations of sensitivity, specificity, accuracy, likelihood ratios, and predictive values before prevalence adjustment

Clinimetric parameter	Formula	Value	95% CI
Sensitivity	(TP/[TP + FN]) ×100	96.1%	93.9%–98.3%
Specificity	(TN/[TN + FP]) ×100	91.4%	85.7%–97.1%
Positive likelihood ratio	Sensitivity/100 – specificity	11.2	5.8–21.7
Negative likelihood ratio	100 – specificity/sensitivity	0.04	0.02–0.07
Positive predictive value	(TP/[TP + FP]) ×100	97.4%	95.6%–99.2%
Negative predictive value	(TN/[TN +FN)) ×100	87.6%	81.1%–94.2%
Pain prevalence	([TP + FN]/[TP + TN + FP + FN]) ×100	76.8%	72.3%–80.8%
Accuracy	([TP + TN]/[TP + TN + FP + FN]) ×100	95.0%	92.9%–97.1%

Note: All values approximated to closest decimal point.
Abbreviations: TP, true positive; FP, false positive; FN, false negative; TN, true negative.

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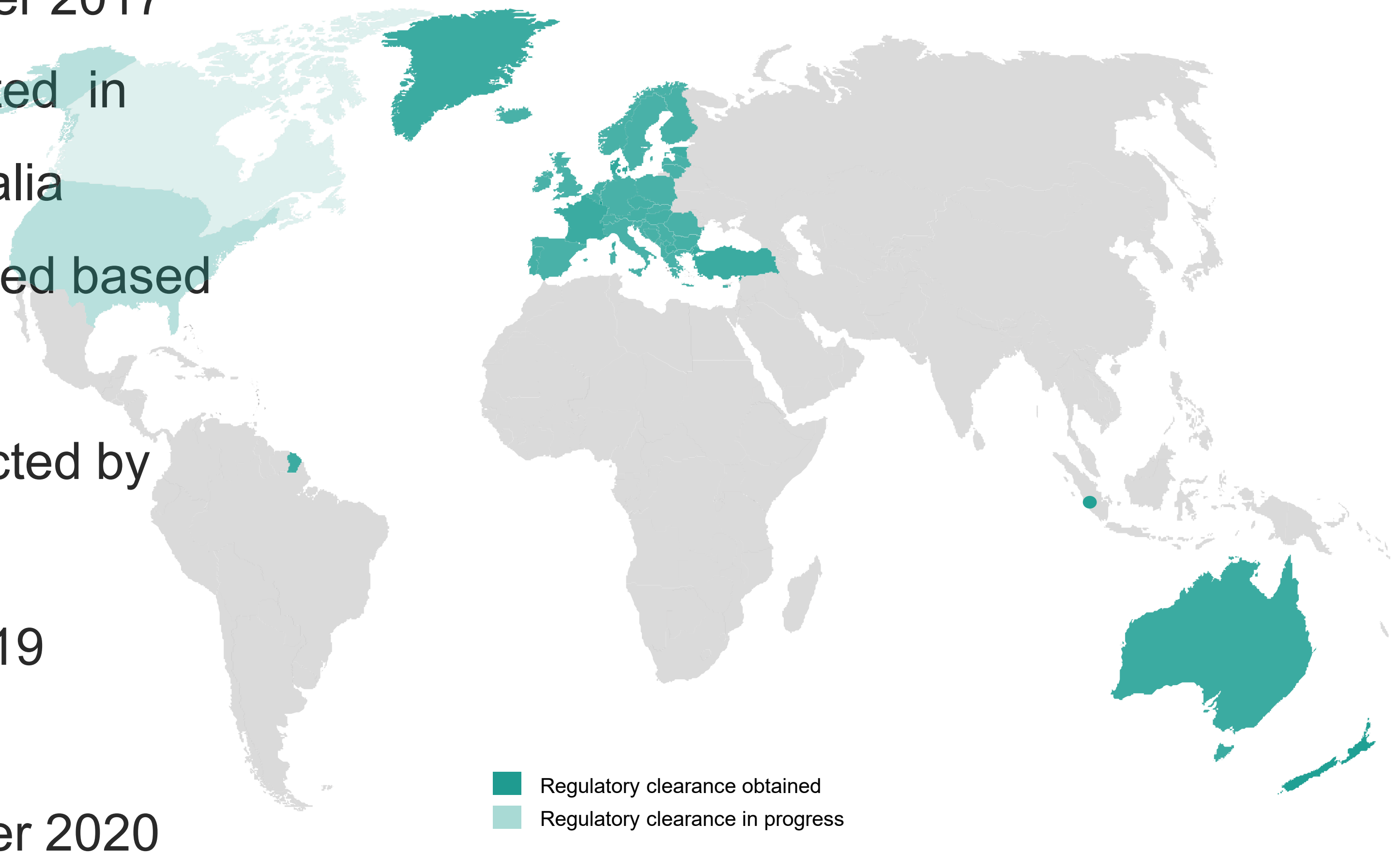
Implementation in Clinical Practice

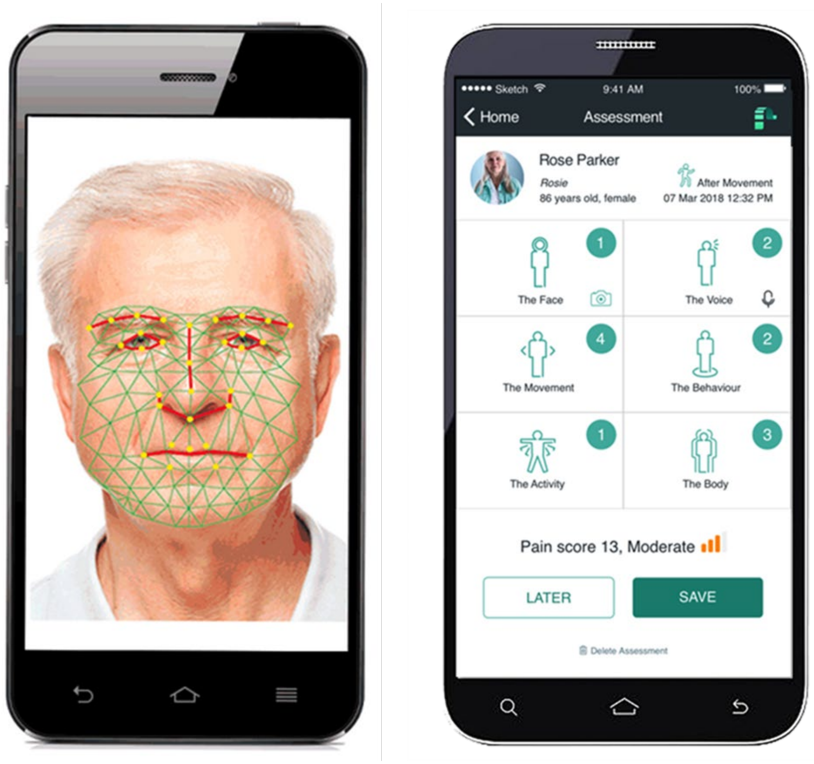
- **Dementia Support Australia** September 2017
- Currently implemented/being implemented in over **1000 aged care facilities** in Australia
- Covering over **120,000 beds** with licenced based agreements
- Over **600,000** pain assessments conducted by over **7600 trained users**
- **Singapore** roll-out started in August 2019
- First client in the **UK** December 2019
- Regulatory clearance **Canada** November 2020
- First **hospital** trial commenced March 2021



Conclusions

- PainChek® is the world's first, clinically validated and regulatory cleared point-of-care app utilizing AI to assist in the assessment of pain in patients with dementia.

- PainChek® has been successfully implemented into clinical practice in Australia and is now entering other UK, NZ and Asian markets.



PainChek®

Intelligent Pain Assessment

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