Differences in Pain Recognition from Animated Facial Expressions: The Importance of Ethnicity and Perceptual Context

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Abstract

People commonly assume that pain is universally displayed, yet there are inconsistencies in pain expression and recognition from facial expressions, with culture, sex, and perceptual context of importance. In this study, we adopted a data-driven approach to test whether pain shows perceptual similarity to other commonly studied emotion categories, and whether this varies across ethnicity, sex, and age of the observer. We also examined whether perceptual context (including internalizing problems, emotion regulation strategies, emotional states, self-esteem, and personality traits) were associated with identifying pain from facial animations. Our results show that with no contextual information provided, participants were more likely to identify anger or disgust rather than pain, with differences emerging regarding ethnicity and sex of both observers' and animations. In addition, a variety of perceptual context variables were associated with identifying pain rather than any other emotion from the animated videos. For White male, Asian female, and Black female animations, ethnicity was significantly associated with identifying pain rather than any other emotion, whereas White participants were less likely in general to identify pain compared to participants in the other ethnicity groups. A greater variety of perceptual context variables predicted identifying pain from the Black male and female animations particularly. These findings suggest the importance of considering cultural and perceptual context factors associated with pain recognition from facial expressions.

1 Introduction

Pain is a universally relatable emotion, though its facial expression has been debated. When in pain, humans tend to scrunch their eyes, bare teeth, and raise cheeks (Prkachin, 2005; Prkachin & Solomon, 2008). People also tend to engage in head movements such as pitch, yaw, and roll when they are in pain (Werner et al., 2018). Similarities in pain expression have also been found among animals, who present grimaced responses to pain (Langford et al., 2010). Despite similarities in facial expressions of pain, however, research has also unearthed

inconsistencies. Besides for teeth baring, eye scrunching, and cheek raising, brow lowering, nose wrinkling, raising the upper lip, closing the eyes, and horizontal mouth stretch have also been identified as pain indicators (Prkachin, 2009). In addition, smiling has been reported as a pain expression (Kunz et al., 2009, 2013) and is attributed to attempting to modulate subjective pain experiences during instances such as for example receiving an injection (Pressman et al., 2020). Children's expressions of pain differ from those of adults, likely due to differences in maturity of neuromuscular systems (Prkachin, 2009). These inconsistencies might largely be due to cultural diversity (e.g., different subpopulation genetics) as well as cultural similarities (Crivelli & Fridlund, 2018). It is therefore by no means certain that humans can correctly identify whether others are in pain from their facial expressions alone.

In line with Basic Emotion Theory, emotions represent discrete states that involve expressive, subjective and physiological mechanisms (Keltner et al., 2019). This view implies that there are a discrete number of emotional categories (e.g., happiness, surprise, sadness, anger, fear, and disgust) with core facial configurations representing each emotion, such as narrowed eyes for anger (Barrett et al., 2019). This so-called *classical view* of emotion perception has received increased pushback from research repeatedly demonstrating that human emotion expressions are far from universal, also known as *theory of constructed emotion* (Barrett, 2017; Barrett et al., 2019). Despite ongoing scholarly debate regarding universality of emotions from facial expressions (Crivelli & Fridlund, 2018; Ekman, 2016), less is known about variability in recognition of pain from faces. This is likely because pain does not fall within the classical emotion paradigm despite being classified as an emotional experience by the International Association for the Study of Pain (Williams, 2003). A recent survey of emotion scientists indicated that only 28% agreed that pain was a biological category with universal expressions (Ekman, 2016). In addition, studies focusing on classical emotion categories indicate that conceptually comparable facial expressions are perceived as similar even after controlling for physical similarity of stimuli, indicating that perceptions of facial expressions reflect differences in conceptual knowledge (Brooks & Freeman, 2018). A study adopting a machine learning approach using video clips from 12 world regions showed that pain had strong perceptual similarity with distress (Cowen et al., 2019). Another study showed that human participants were not as accurate as machine learning models in identifying real from faked pain (Littlewort et al., 2007). More research is thus required regarding perceptual similarity between pain and other emotions.

Scholars have suggested that pain can be considered a signal or a “behavioural source of evidence” representing social communication about internal states particularly adapted to interpersonal contexts (Prkachin, 2009, p. 53). Emerging evidence supports the biologically rooted *behavioural ecology view of facial displays* (BECV), which attempts to explain emotional displays as conventionalised via cultural selection (Crivelli & Fridlund, 2018). Unlike the classical emotion paradigms including basic emotions theory (Ekman, 2016), BECV does not assume that facial expressions are based in brain processes or specific mental states (Crivelli & Fridlund, 2018). Rather, facial expressions of emotions are assumed to have become stereotyped via natural and cultural selection and signal social action (Crivelli & Fridlund, 2018). Individuals expressing pain are not demonstrating to others what is hidden inside of their minds; rather, they are signalling what they are about to do. According to this view, then, people are more likely to infer that someone is in pain from their facial expression if they belong to a similar culture. Research on basic emotions finds that they vary across contexts, and that context matters in terms of emotion interpretation (Aviezer et al., 2008). People who engage in similar cultural contexts are more likely to experience similar patterns of emotions and are rewarded for fitting in emotionally (De Leersnyder, 2017). Thus, a lack

of context between observer and expressor likely impacts perception of pain from facial expressions.

Research findings support this view. Human empathic responses appear weakened when viewing pain expressed by other- rather than same-race individuals (Azevedo et al., 2013; Contreras-Huerta et al., 2013; Xu et al., 2009). US participants have reliably demonstrated a greater ability to identify pain on White compared to Black male faces, which is likely due to social as well as neural biases (Mende-Siedlecki et al., 2019, 2021). Research has identified a bias toward recognizing negative emotion on Black male faces (Mende-Siedlecki et al., 2021). European Americans with high implicit prejudice scores report seeing hostility on animated African American faces that appears more quickly and lingers longer (Hugenberg & Bodenhausen, 2003). These cultural differences point to cultural selection of facial displays of pain, making it less likely for people to identify pain on faces that are unlike their own.

Variations in emotion perception and expression are also apparent for females and males, with gender expressions varying by culture and time. Despite differences in norms across cultures, female emotion expression is more acceptable compared to that of males (Chaplin, 2015). Males are expected to demonstrate less of the ‘tender’ emotions, including anxiety and sadness (Chaplin, 2015). Women show greater ability to perceive and respond to positively valenced emotions from facial expressions compared to men, which is likely due to higher perceptual sensitivity to social cues (Donges et al., 2012). Humans show a tendency to detect anger in males and sadness in females (Hess & Hareli, 2017). Differences in pain perception and expression between males and females has been relatively unexplored, however, and with mixed findings (Kunz et al., 2006). For instance, although studies have found no differences between males and females in terms of facial expressiveness of pain, there are significant effects of sex on the link between self-reports and facial expressions of pain, with higher effects for women (Kunz et al., 2006). More knowledge is therefore required regarding differences in pain perception from facial expressions depending on the sex of the pain expressor as well as the observer.

In addition, *perceptual context* including emotional and physical states of the observer might impact emotion interpretation. Symptoms of internalizing, representing an empirically derived dimension classifying problem behaviours characterized by inner distress (Achenbach & McConaughy, 1997) and classified by a range of clinical and subclinical phenomena including anxiety, social anxiety, and depression (Hankin et al., 2016; Krueger & Markon, 2006; Waszczuk et al., 2016), are often linked with biased perceptions of own and others’ emotions. For instance, depressive affect is linked to a negativity bias (see Anderson et al., 2011 for a meta-analysis), which is stronger for females, as they demonstrate more rapid negative emotion recognition compared to non-depressed observers (Hampson et al., 2022). Generalised anxiety is also associated with increased attention to threat-related information (Britton et al., 2011). Socially anxious individuals tend to struggle in identifying emotion from faces, as studies have identified a lower threshold for decoding emotions but a more frequent incorrect classification of low intensity emotions (Button et al., 2013). Individuals with high social anxiety also identify anger from faces more readily than other emotions (Torro-Alves et al., 2016). On a similar note, shyness – a childhood forerunner of social anxiety and social anxiety disorder, is related to a stronger misidentification of fear compared to other emotions (Gao et al., 2014). Internalizing problems are also linked to impaired emotion regulation strategies, including rumination and suppression (Joormann, 2016). US minority individuals often carefully control their emotional expressions so as not

to upset those in the more socially powerful majority (i.e., European Americans; Keltner et al., 2003), as demonstrated by higher levels of emotional suppression reported by Latino, Asian and Black individuals (Gross & John, 2003). In addition, self-esteem is reduced when viewing angry faces with a direct gaze (Lamer et al., 2015). Thus, observers' emotional states and traits are associated with what is inferred from facial expressions – though not much is known about how this is related to pain perception.

In addition to internalizing as a perceptual context, personality traits can also impact pain perception of emotion via faces. Personality can be defined by specific tendencies to emote, both in terms of experience and expression (Dacher, 1996; Watson & Clark, 1992). Although this has received less research attention in conjunction with pain perception, research shows that higher levels of agreeableness and conscientiousness predict perceptions of higher pain intensity on synthetic faces (Courbalay et al., 2015). There are associations between emotional communication patterns and expressiveness of personality traits, as a predisposition for positive emotion expression might evoke positive interactions with other people (Dacher, 1996). In addition, extraversion, openness to experience, agreeableness and conscientiousness are associated with positive self-reported emotions, whereas neuroticism (or emotional instability) is associated with negative emotions (Dacher, 1996). A recent large-scale investigation showed that people's facial expressions were formed as part of an interpretation of personality structure unique to their culture (Oh et al., 2022). Nevertheless, more knowledge regarding how observer's personality traits are related to perception of pain is required.

In this study, we adopt a data-driven approach to test whether the commonly assumed expressions of pain (including brow lowering, tightening and closing of the eye lids, and nose wrinkling/upper lip raising, as well as associated head movements) are apparent from facial animations designed to exhibit dynamic expressions of high-intensity pain. We test the assumption that facial expressions of pain are distinctly recognizable from other commonly studied emotions (happiness, sadness, anger, fear, disgust) using a series of animated male and female White, Black, and Asian faces, respectively. We explore whether pain can be reliably identified if no contextual information is available (as methodological context, such as what information is shown to study participants before they guess facial expressions, can impact emotion perception; Pochedly et al., 2012). First, we test whether pain shows perceptual similarity to other commonly studied emotional categories and whether this varies across ethnicity, sex, and age of the observer. Second, we examine whether perceptual context (including internalizing problems, emotion regulation strategies, current emotional states, self-esteem, and personality traits) predicts identifying pain from facial animations. The research questions for this study are: given lack of context, 1) what is the perceptual similarity of pain to other commonly studied emotional categories given age, ethnicity, and sex of the observers, and 2) what perceptual context variables predict the likelihood of identifying pain from facial animations?

2 Materials and Methods

2.1 Participants

520 UK-based adults (18-60 years; $M = 42$; 260 females, 259 males, 1 preferring not to say) were recruited via Qualtrics and paid £5.51 for taking part. There were 75 female and 57 male White participants; 72 female and 57 male South Asian participants; 48 female and 80 male East Asian participants, and 65 female and 65 male Black participants. These broad ethnic group categories were chosen as they are representative of the UK population at large.

The participants lived with 3.06 other individuals on average ($SD = 1.45$), with 38% living with family, 36% living with partner/spouse, 6.7% living with peers, 17.1% living alone, and 1.9% indicating 'other'. The average number of rooms in the home was 4.17. 2.3% did not complete GCSE/CSE/O-levels; 14% completed GCSE/CSE/O-levels; 4.4% completed a post-16 vocational course; 21.2% completed A-levels; 33.1% completed an undergraduate degree; 22.7% completed a postgraduate degree, and 2.3% were still in education. All participants provided full data.

Participants had to sign a consent form informing them about the study purpose, data records, mitigation procedures in case of harm, and contact information for the PI. The study received ethics approval from the Imperial College Research Governance and Integrity Team (no. 20IC6295) and was conducted in accordance with the World Medical Association's Declaration of Helsinki.

2.2 Animated videos

Using a data-driven approach to generate animated faces, we created a series of videos showing male and female White, Black, and Asian faces expressing highly intense pain (shown in Figure 1). The facial pain expressions as in this work were synthesized based on a set of Action Units (AUs) identified as relevant to pain and are based on the taxonomic Facial Action Coding System (FACS; Ekman & Friesen, 1978). Four AUs consistently associated with pain were incorporated in the animations, including brow lowering (AU4), tightening and closing of the eye lids (AU7), and nose wrinkling (AU9)/upper lip raising (AU10) (Prkachin & Solomon, 2008). Pain expressions were generated using a modified version of FACSHuman (Gilbert et al., 2018), by setting the activation intensities for the four AUs based on our previous studies (Lalitharatne et al., 2021; Lalitharatne et al., 2022) on the effective weightings of AUs on perceived pain intensity. For rendering of the facial expressions and final videos, Makehuman (www.makehumancommunity.org) and Blender (Community, 2018) were used. White, Black, and Asian were chosen as broad categories as it was not possible to generate a South Asian face using the software. Head movements associated with pain were created with matching egocentric rotation angles called pitch, yaw, and roll that appear more frequently when people are in pain (Werner et al., 2018). Figure 1 shows screenshots of animated faces as they were expressing high-intensity pain.

2.3 Measures

We measured several indices of participant perceptual context, including internalizing problems (state anxiety, generalized anxiety, depressive symptoms, shyness, social anxiety) and self-esteem, as well as typical emotion regulation strategies, current emotional states, and personality traits. To compare with findings from prior literature, we used a categorical measure of emotions.

2.3.1 State anxiety was measured using the shortened version of the Spielberger State-Trait Anxiety inventory (STAI; Marteau & Bekker, 1992). The scale comprises 6 items pertaining to how the participants were feeling during the past week. Example items include "upset," "tense," and "content" (reversed), with response items ranging from Not at all (1), Somewhat (2), Moderately (3), to Very much (4). The scale has demonstrated acceptable reliability and validity in previous studies (Marteau & Bekker, 1992). The Cronbach's α reliability for this study was .81.

2.3.2 Generalized anxiety was measured using a brief 7-item measure to assess generalized anxiety disorder (Spitzer et al., 2006). The questions refer to the past two weeks, with example items including 'feeling anxious, nervous, or on edge', 'trouble relaxing', and 'becoming easily annoyed or irritable'. The response items ranged from Not at all (1), Several days (2), More than half the days (3) to Nearly every day (4). This measure has shown good reliability, as well as criterion, construct, factorial, and procedural validity in previous research (Spitzer et al., 2006). The Cronbach's α reliability in this study was .93.

2.3.3 Depressive symptoms were measured with the 10-item shortened version (Cheng et al., 2006) of the widely-used Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977). The measure includes symptoms such as worry, sadness, hopelessness, lethargy, and poor appetite. The shortened version has previously demonstrated good factorial validity (Cheng et al., 2006). The items refer to the past week, with examples including "I felt down and unhappy," "I felt lonely, like I didn't have any friends," and "I felt like I was too tired to do things." The response items ranged from Not at all (1), Very seldom (2), Now and then (3), to Often (4). The Cronbach's α reliability was .90.

2.3.4 Shyness was measured using the Revised Buss and Cheek scale (Crozier, 2005). Examples of items were "I feel tense when I'm with people I don't know well," "I am socially somewhat awkward," and "I am often uncomfortable at parties and other social functions." The response options ranged from (1) Very uncharacteristic or untrue, (2) Uncharacteristic, (3) Neutral, (4) Characteristic, to (5) Very characteristic or true. The Cronbach's α reliability was .86.

2.3.5 Social anxiety was measured using the Social Phobia Screening Questionnaire (Furmark et al., 1999), which asks about fears in eight social situations. Example items include "speaking in front of a group of people," "maintaining a conversation with someone unfamiliar," and "initiating a conversation with someone unfamiliar." Participants rated their fears on a four-point scale ranging from (0) No distress to (4) Severe distress. The Cronbach's α reliability was .93.

2.3.6 Self-esteem was measured using the well-known Rosenberg (1979) scale. The item examples include "Considering all things, you are pleased with yourself," "You are able to do things as well as most other people", and "Sometimes you feel you are of no use (reversed)." The response items ranged from Don't agree at all (1), Don't particularly agree (2), Agree pretty well (3), to Agree completely (4). The Cronbach's α reliability was .84.

2.3.7 Emotion regulation strategies were measured via reappraisal and suppression from the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). Examples of reappraisal items include "I control my emotions by changing the way I think about the situation I'm in", "When I want to feel less negative emotion, I change the way I'm thinking about the situation", and "When I want to feel more positive emotion, I change the way I'm thinking about the situation". Examples of suppression items are "I control my emotions by not expressing them", "I keep my emotions to myself", and "When I am feeling positive emotions, I am careful not to express them". The response items ranged from Not at all characteristic of me (1) to Very characteristic of me (7). The Cronbach's α reliability for reappraisal was .88, and for suppression was .76.

2.3.8 Daily affect was measured using positive active (excited, enthusiastic, happy) and deactive (satisfied, calm, relaxed) affect, as well as negative active (nervous, embarrassed,

upset) and deactive (sad, disappointed, bored) daily affect (Nezlek & Kuppens, 2008). The questions referred to any point today, with example items “Excited”, “Satisfied”, and “Bored”. The response items ranged from Did not feel this way at all (1) to Felt this way very strongly (7). The Cronbach’s α reliability for positive active as well as deactive affect was .87, and for negative active as well as deactive affect was .80.

2.3.9 Personality traits were measured using the Big-5 Personality Inventory (John & Srivastava, 1999). The scale has 44 items measuring extraversion (e.g., “I see myself as someone who is talkative”), agreeableness (e.g., “I see myself as someone who is helpful and unselfish with others”), conscientiousness (e.g., “I see myself as someone who does a thorough job”), emotional instability (e.g., “I see myself as someone who worries a lot”), and openness to experience (e.g., “I see myself as someone who is curious about many different things”). The participants responded on a 5-point Likert-scale ranging from Disagree strongly (1), Disagree somewhat (2), Neither agree nor disagree (3), Agree somewhat (4) to Agree strongly (5). The Cronbach’s α reliabilities were .76 for extraversion, .71 for agreeableness, .78 for conscientiousness, .77 for emotional instability, and .69 for openness to experience.

2.3.10 Emotion identification was measured using the widely-used discrete categorisations from basic emotions theory (Ekman, 2016). These include ‘happiness’, ‘sadness’, ‘anger’, ‘fear’, and ‘disgust’. We also added a category called ‘none’ for those who felt the animations were not emoting, as well as ‘pain’ as our comparison category of interest.

2.4 Procedure

After consenting to take part, the study participants watched the facial animations in random order and were asked to identify the emotion expressed using a forced-choice method (happiness, sadness, anger, pain, fear, disgust, or none), with no additional background information provided. Participants were then asked to answer questions about perceptual context, emotion regulation strategies, current emotional states, and personality traits, followed by questions on demographics.

2.5 Analytical strategy

To examine perceptual overlap between emotional categories, we inferred decision probabilities of emotion identification given participant age, ethnicity, and sex by designing and modelling a Bayesian Belief Network (BBN) using Python 3.8 platform with *bnlearn*. BBNs are graphical representations of conditional dependencies between variables (Dagum & Chavez, 1993). To examine what contextual variables predicted the likelihood of identifying pain from facial animations, we conducted a series of stepwise multivariate logistic regressions using SPSS v. 27.

Results

2.6 Descriptives

Table 1 shows the means for males and females on main study variables. Independent sample t-tests showed that females scored significantly higher on state anxiety, social anxiety, agreeableness, and emotional instability, whereas males scored significantly higher on age and emotion suppression. We also ran a one-way ANOVA with Tukey’s post hoc tests comparing participants according to their ethnic group identification (White, South Asian, East Asian, Black) on main study variables (shown in Table 2). White participants were

significantly older than the participants in the other ethnic groupings. Black and South Asian participants scored significantly higher compared to East Asian participants on negative active affect (feeling nervous, embarrassed, or upset at any point that day), negative deactive affect (feeling sad, disappointed, or bored at any point that day), and openness to experience.

Table 3 shows correlations between main study variables. These were largely significant and according to expectations (Gross & John, 2003; Merikangas et al., 2010; Schmitt et al., 2017). There were high positive correlations between symptoms of internalizing, and high negative correlations between internalizing and self-esteem. Reappraisal was largely negatively correlated whereas suppression was largely positively correlated with internalizing. Positive active (excited, enthusiastic, happy) and deactive (satisfied, calm, relaxed) affect were negatively, whereas negative (nervous, embarrassed, upset) active and deactive (sad, disappointed, bored) affect were positively correlated with internalizing. Big-5 personality traits showed intercorrelations according to expectations, as extraversion, agreeableness, conscientiousness, and openness to experience were negatively correlated whereas emotional instability was positively correlated with internalizing (Karsten et al., 2012).

2.7 Perceptual similarity of pain to other emotions

To explore our first research question regarding the perceptual similarity of pain to other commonly studied emotional categories given age, ethnicity, and sex of the observers, we explored the scores for identifying different emotions for each of the video animations (shown in Table 4, with largest categories shown in bold). We conducted BBNs with probabilities, depicted in Figure 2 and illustrated using heatmaps. On the X-axis, the participant age was categorized as below or above 33 (median age of the survey participants), ethnicity (White, South Asian, East Asian, and Black), and sex (female, male) as parent nodes, with a child node representing the type of facial expression rendered on the animated clips (happiness, sadness, anger, pain, fear, disgust, or none). As the figure shows, none of the probabilities range higher than .30, and only the highest probabilities will be discussed below.

For White female animations, there was a higher probability of identifying anger and disgust rather than pain across age, ethnicity, and sex combinations. The probabilities to identify anger were highest among older East Asian males, both younger and older white females, and younger White participants. Older East Asian males, younger South Asian females, older East Asian participants and younger East Asian females and males had the highest probability of identifying disgust on White female animations. For White male animations, older East Asian males, younger White females, and younger Black males had the highest probability of identifying anger. Older White males and females had the highest probability of identifying disgust from the White male animations.

For Asian female animations, the probability was highest to identify disgust instead of pain. These probabilities were high across the board for White, Black, and East Asian participants, though slightly lower for the South Asian participants. A very similar tendency for identifying disgust instead of pain was also apparent for Asian male animations.

For the Black female animations, there was a higher probability of identifying anger and disgust rather than pain. For anger, the probabilities were highest among younger females, and younger and older South Asian males. The probabilities for identifying disgust were highest among younger White participants, older White females, younger East Asian males,

and older East Asian females. For the Black male animations, despite perceptual overlap with disgust, the highest probability was to identify anger rather than pain. As Figure 2 shows, this probability was higher among younger Black males, older White females, older White participants, younger East Asian females, older East Asian males, younger White females, younger Black females, females, older females, older South Asian participants, younger White males, younger South Asian females, and older South Asian males.

To summarise, without contextual information, participants tended to identify anger or disgust from animated faces designed to express high-intensity pain. There was a general tendency to identify disgust rather than pain on the Asian animations, and an overlap between identifying disgust and anger for the White animations. For the Black female animations, a similar overlap was found, but there was a stronger tendency to identify anger than pain from the Black male animations.

2.8 Perceptual context variables predicting the likelihood of identifying pain

To answer our second question, we collapsed the emotion identification variable to pain vs. other emotions to preserve statistical power (as some of the categories had low numbers which prevented adopting a multinomial approach). Of 520 participants in total, there were 109 individuals identifying pain on the White female and 130 on the White male face, 155 identified pain on the Asian female and 184 on the Asian male face, and 101 identified pain on the Black female and 99 on the Black male face.

Due to the exploratory nature of the analyses, we used a series of stepwise logistic regression models including participant ethnicity (White, South Asian, East Asian and Black), sex (female, male), age, internalizing symptoms (state anxiety, generalized anxiety, depressive symptoms, shyness, and social anxiety), self-esteem, emotion regulation strategies (reappraisal and suppression), daily affect (positive and negative active and deactive affect), and Big-5 personality traits (extraversion, agreeableness, conscientiousness, emotional instability and openness to experience) to predict identifying pain (1) vs. any other emotion (0). The models used data from 519 participants as the one participant not providing information about sex was excluded. Differences between ethnicity groups and females vs. males were tested using simple contrasts (with White and females as categories of comparison). We ran six separate logistic regression models predicting pain on female and male White, Black, and Asian facial animations, respectively, resulting in six parsimonious models.

We checked model diagnostics for outliers to justify the choice of final models by saving the model residuals. According to recommendations, Cook's distance should be less than 1; the leverage (calculated as $k+1/N$, where k is the number of predictors and N = sample size) should be between 0 and 1; studentized and standardised residuals should only have 5% of cases outside ± 1.96 and 1% outside ± 2.58 , and the df Beta for the Constant should be less than 1 (Field, 2013). For all models, the diagnostics were within the prescribed ranges, and all final models showed good fit (fit indices are shown below Table 5).

The results for the logistic regressions are shown in Table 5 (with significant predictors in bold). For the White female animations, the odds were 1.2 times higher to identify pain from participants who scored high on negative active affect (feeling nervous, embarrassed, or upset at any point that day). Participants identifying as South Asian had 2.16 times higher odds to identify pain from the White male animations compared to those identifying as White. In addition, the odds were nearly 1.2 times higher to identify pain from White male animations

for those who scored high on positive active affect (feeling excited, enthusiastic, or happy at any point that day).

For the female Asian animations, identifying as South Asian increased the odds to 2.06 to identify pain compared to identifying as White. The odds were also nearly 1.3 times higher to identify pain from Asian female animations for participants who scored high on positive active affect (feeling excited, enthusiastic, happy). For the male Asian animations, the odds were 1.15 higher to identify pain for participants who scored high on positive deactive affect (feeling satisfied, calm, or relaxed that day).

For the Black animations, a more intricate picture of the importance of perceptual context emerged. For the Black female animations, participants identifying as South Asian had 3.14 the odds, those identifying as East Asian had 4.89 the odds, and those identifying as Black had 12.53 the odds to identify pain compared to those identifying as White. In addition, with increasing state anxiety, the odds decreased to 1.60 to identify pain from Black female animations. With increasing shyness, the odds increased to 1.60, and with increasing agreeableness, the odds decreased to 0.86 to identify pain from Black female animations. For the Black male animations, increasing generalised anxiety was associated with 2.19 the odds to identify pain. In addition, for increased negative deactive affect (feeling sad, disappointed, bored), conscientiousness, and emotional instability, the odds to identify pain from Black male animations decreased to .79, .42 and .45, respectively.

To summarise, a variety of perceptual context variables were associated with identifying pain rather than any other emotion from the animated videos. For White male, Asian female, and Black female animations, ethnicity was significantly associated with identifying pain rather than any other emotion. For Black female animations, identifying as Black was associated with the highest odds whereas identifying as White was associated with the lowest odds to identify pain. In addition, a larger variety of perceptual context variables predicted identifying pain from the Black male and female animations particularly.

3 Discussion

Although previous research has shown that cultural and perceptual characteristics of observers can impact emotion recognition, much of this research has examined classical emotion categories such as happiness, sadness, anger, pain, fear, and disgust. Less is known about recognition of pain from facial expressions, however, but there are indications that humans are not necessarily apt in recognising when someone is in pain despite assumptions of universality. In this study, we adopted a data-driven approach to test whether pain was identifiable from commonly assumed facial features on dynamic animated facial expressions, given no contextual information. We tested whether pain showed perceptual similarity to other commonly studied emotional categories and examined whether perceptual context predicted identifying pain from a variety of animations.

With no contextual information provided, our participants were more likely to identify anger or disgust rather than pain from dynamic facial animations designed to express high-intensity pain. An alternative explanation for these results might be perceptual confusion in terms of expression similarity, as faces from conceptually comparable categories such as anger and fear are often perceived as similar (Brooks & Freeman, 2018). Previous research has also identified a strong perceptual overlap between pain and distress (Cowen et al., 2019). Some differences according to the ethnic group of the animation and the observer emerged, however. Asian animations were more likely to be rated as showing disgust over pain,

whereas an overlap between disgust and anger was more apparent for the White animations as well as Black female animations. For the Black male animations, however, the participants had a higher probability of identifying anger over pain. This is somewhat contrary to previous findings showing a more reliable pain identification from White compared to Black faces among US participants (Mende-Siedlecki et al., 2019, 2021). Nevertheless, comparisons with prior literature are not straightforward, as most studies have relied on the use of static expressions even though faces typically represent complex dynamical systems (Jack & Schyns, 2015). In addition, much research has used pictures of humans whereas we used dynamic animations starting with a neutral expression and moving to high-intensity pain, which might have contributed to differences in results.

Prior studies have identified a bias toward recognizing negative emotions on Black male faces (Mende-Siedlecki et al., 2021), with human empathic responses appearing weakened when viewing pain expressed by other- rather than same-race individuals (Azevedo et al., 2013; Contreras-Huerta et al., 2013; Xu et al., 2009). Westerners also present a distinct set of facial movements common to each of the typically studied six basic emotions, whereas Easterners do not (Jack et al., 2012). Our results present a more complex picture, however. Despite expectations, gender per se was not associated with prediction of pain in any of the models. Rather, participants identifying as White had lower odds of identifying pain compared to South Asian participants from White male, Asian female, and Black female animations. For pain prediction from White and Asian animations, current affective states seemed to matter. Feeling excited, enthusiastic, or happy was associated with higher odds of identifying pain from White male and Asian female animations. Feeling satisfied, calm, or relaxed also increased the odds of identifying pain from Asian female animations. For pain prediction from Black animations, however, a more complex picture emerged. For Black female animations, all participants were superior to those identifying as White in predicting pain, with participants identifying as Black having nearly 13 times the odds of identifying pain rather than other emotions. Internalising symptoms and personality traits also seemed to matter, as participants with higher state anxiety and agreeableness had lower odds of identifying pain, whereas those with higher shyness had higher odds of identifying pain from Black female animations. For Black male animations, higher generalised anxiety increased the odds of identifying pain, whereas negative deactive affect, conscientiousness, and emotional instability decreased the odds to identify pain compared to any of the other emotional categories.

In our study, participants identifying as White were less likely to see pain from facial animations in general – including White faces as well. Indeed, those identifying as South Asian were largely superior in identifying pain compared to the other ethnicities, which might indicate that people from South Asia are more attuned to others' empathic responses in general. Being White in the UK today might involve fewer requirements for emotional processing of negative emotions according to cultural norms, resulting in less accurate recognition of pain from all faces, including White. It was also apparent from our results that perceptual context as well as ethnicity had a more complex role in emotion identification from Black male and female animations compared to White and Asian animations. Current affective state was associated with identifying pain from White and Asian animations, but internalising symptoms as well as personality traits in addition to ethnicity were predictive of identifying pain from Black animations, especially for Black female faces. In line with the behavioural ecology view of facial displays, which postulates that people express emotions conventionalized via cultural selection (Crivelli & Fridlund, 2018), one explanation could be that people in general are less exposed to empathic responses from Black people, as they are

less visible in the media for instance. Arguably, Black females are one of the most marginalised and least visible groups in the UK today. Therefore, processing emotional information from less familiar faces might involve human perceptual context to a higher degree compared to faces that are dominant and more visible such as White faces. More research is required in understanding how empathic responses to pain are associated with exposure to other cultures.

Our study is not without limitations. First, we used video animations based on common expressions of pain, including brow lowering, tightening and closing of the eye lids, and nose wrinkling/upper lip raising, as well as associated head movements. Adding additional indicators of pain such as audio signals and body movements would help improve future research exploring pain recognition. Nevertheless, there are instances where verbal and other information is not possible (such as interacting with infants or individuals with communication deficits; Prkachin, 2009), making facial expressions particularly valuable for the study of pain perception. Another limitation of our study is that we have captured observers' perceptions of pain as well as other information using a cross-sectional survey design. Emotions can be seen as interpersonal systems, whereby components of emotions and their processing appear during interactions with humans with similar emotional components and processes (Butler, 2017). We also relied on the use of facial animations rather than using videos of humans. As such, our data focused on the observer alone rather than more naturalistic settings where interaction helps to guide emotion perception. We also used forced-choice categorizations of emotions to compare our results to prior literature. Future research could adopt open-ended questions of emotions and involve dyadic or triadic interactions between people to understand more about how pain is perceived. Comparisons between using facial expressions of pain comparing animations with humans would also be useful.

Despite these limitations, our study has several strengths. We have used a data-driven approach in generating White, Asian and Black female and male animations, treating the face as a complex dynamical system (Jack & Schyns, 2015) compared to much previous work that relies on static facial expressions. In addition, emotions are not perceived devoid of contextual factors (Keltner et al., 2019), yet perceptual context has received inadequate research attention (Brooks & Freeman, 2018). To our knowledge, this is the first study to explore several important variables related to observers' emotional states and traits that might contribute to pain perception from facial expressions. We have used a large sample of individuals representing common ethnic categories in the UK and placed importance on collecting equal amounts of data in terms of ethnic categories as well as sex. As such, therefore our study contributes to understanding more about perceptual overlaps of pain to other emotions, as well as perceptual context factors that contribute to pain recognition.

One of the more common assumptions about emotion perception is that people are correctly able to infer what others are feeling from their facial expressions (Barrett et al., 2019). This notion is so widespread and pervasive, it helps to guide everything from policy decisions and educational practices to treatment of illnesses (Barrett et al., 2019). Nevertheless, there is growing consensus that context matters in terms of interpreting what people might be feeling. Our findings suggest the importance of considering cultural and perceptual context factors of the observers that are related to pain recognition from others' faces. There are several reasons why identifying pain is important, not the least in medical contexts. Despite growing technological advances in healthcare, physical examination remains a key element to establishing understanding, trust, and confidence in doctor-patient relationships (Iida &

Nishigori, 2016; Phoon, 2000). While emotions are typically derived from facial expressions, gestures, voice intonations, behaviour, postures, autonomic response, and scent (Grabowski et al., 2019; Keltner et al., 2019), understanding patients' pain by monitoring their facial expressions is a key feature of physical examination. If doctors assume that pain is universally expressed or disregard the effect of their own emotional states or culture on pain interpretation, this could impact the quality of doctor-patient interaction as well as accuracy of diagnostic and treatment outcomes. Recent evidence from a large UK study shows considerable disparities in healthcare for individuals from ethnic minorities (Watkinson et al., 2021). Although accurate pain recognition is not necessarily the cure for structural racism, it might aid in more empathically attuned interactions between healthcare workers and individuals from ethnic minorities. Cultural sensitivity training for pain recognition could be incorporated into future training for medical students and educators to help combat cultural and contextual perception biases.

4 Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

5 Author Contributions

NvZ, TDL, and TN designed the research. NvZ performed the research. YT created facial animations. NvZ and TDL analysed the data. NvZ and TDL wrote the paper. TN contributed to draft versions of study.

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8 Data Availability Statement

All study data and supporting information are available via OSF: osf.io/9fspd.

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1 **Table 1.** *Descriptives for main study variables with t-tests for differences between females and males.*

Variable	<i>M</i> Females (<i>SD</i>)	<i>M</i> Males (<i>SD</i>)	<i>t</i> -value	<i>df</i>	<i>Two-sided p.</i>
Age	34.02 (10.70)	36.42 (11.42)	-2.48	517	.01
State anxiety	2.42 (.69)	2.26 (.68)	2.58	517	.01
Generalised anxiety	2.14 (.85)	2.05 (.79)	1.22	517	.22
Depressive symptoms	2.35 (.73)	2.28 (.70)	1.06	517	.29
Social anxiety	2.91 (.84)	2.71 (.91)	2.56	517	.01
Shyness	3.01 (.67)	2.92 (.69)	1.48	517	.14
Self-esteem	2.69 (.61)	2.75 (.58)	-1.24	517	.22
Reappraisal	4.72 (1.21)	4.59 (1.18)	1.32	517	.19
Suppression	4.34 (1.34)	4.60 (1.14)	-2.39	517	.02
Positive active affect	3.97 (1.59)	4.08 (1.58)	-.73	517	.46
Positive deactive affect	4.50 (1.45)	4.56 (1.43)	-.42	517	.67
Negative active affect	3.18 (1.58)	3.17 (1.61)	.03	517	.98
Negative deactive affect	3.42 (1.68)	3.41 (1.58)	.05	517	.96
Extraversion	3.02 (.70)	3.00 (.65)	.41	517	.69
Agreeableness	3.58 (.59)	3.46 (.58)	2.25	517	.03
Conscientiousness	3.50 (.64)	3.46 (.66)	.77	517	.45
Emotional instability	3.04 (.70)	2.86 (.71)	2.81	517	.01
Openness to experience	3.30 (.57)	3.34 (.51)	-.91	517	.36

2
3

4 **Table 2.** ANOVAs with Tukey's post hoc tests comparing participants in self-reported ethnic categories on main study variables.

Study variable	Ethnic Category	N	Mean	SD	95 CI%		df	F	Sig.
Age	White (a)	132	39.43 ^{bcd}	11.58	37.44	41.43	3	10.82	<.001
	South Asian (b)	130	34.63 ^a	10.16	32.87	36.39			
	East Asian (c)	128	34.73 ^a	11.06	32.79	36.66			
	Black (d)	130	31.97 ^a	10.36	30.17	33.77			
State anxiety	White (a)	132	2.34	.67	2.22	2.45	3	.33	.80
	South Asian (b)	130	2.39	.68	2.27	2.50			
	East Asian (c)	128	2.30	.70	2.18	2.42			
	Black (d)	130	2.34	.70	2.22	2.46			
Generalised anxiety	White (a)	132	2.09	.86	1.94	2.24	3	.40	.76
	South Asian (b)	130	2.12	.80	1.98	2.26			
	East Asian (c)	128	2.03	.81	1.89	2.17			
	Black (d)	130	2.13	.83	1.98	2.27			
Depressive symptoms	White (a)	132	2.26	.73	2.13	2.38	3	.89	.45
	South Asian (b)	130	2.39	.64	2.28	2.50			
	East Asian (c)	128	2.28	.73	2.15	2.41			
	Black (d)	130	2.34	.75	2.21	2.47			
Social anxiety	White (a)	132	2.76	.91	2.60	2.92	3	.70	.55
	South Asian (b)	130	2.83	.88	2.68	2.98			
	East Asian (c)	128	2.76	.86	2.61	2.91			
	Black (d)	130	2.89	.89	2.74	3.05			
Shyness	White (a)	132	2.99	.79	2.85	3.12	3	.30	.82
	South Asian (b)	130	2.98	.63	2.87	3.09			
	East Asian (c)	128	2.97	.69	2.85	3.09			
	Black (d)	130	2.91	.61	2.81	3.02			
Self-esteem	White (a)	132	2.68	.66	2.57	2.80	3	.45	.72
	South Asian (b)	130	2.72	.47	2.64	2.80			
	East Asian (c)	128	2.71	.64	2.60	2.83			
	Black (d)	130	2.77	.59	2.67	2.87			
Reappraisal	White (a)	132	4.57	1.14	4.38	4.77	3	1.41	.24
	South Asian (b)	130	4.78	1.13	4.59	4.98			
	East Asian (c)	128	4.52	1.17	4.32	4.73			
	Black (d)	130	4.73	1.32	4.51	4.96			

Pain Recognition from Facial Animations

Suppression	White (a)	132	4.42	1.21	4.21	4.63	3	.78	.51
	South Asian (b)	130	4.60	1.35	4.37	4.83			
	East Asian (c)	128	4.50	1.11	4.30	4.69			
	Black (d)	130	4.38	1.32	4.15	4.61			
Positive active affect	White (a)	132	3.82	1.54	3.55	4.08	3	2.18	.09
	South Asian (b)	130	4.24	1.59	3.96	4.51			
	East Asian (c)	128	3.89	1.60	3.61	4.17			
	Black (d)	130	4.16	1.54	3.89	4.43			
Positive deactive affect	White (a)	132	4.56	1.32	4.34	4.79	3	.49	.67
	South Asian (b)	130	4.63	1.52	4.36	4.89			
	East Asian (c)	128	4.42	1.39	4.17	4.66			
	Black (d)	130	4.50	1.53	4.24	4.77			
Negative active affect	White (a)	132	2.97	1.63	2.69	3.25	3	5.64	<.001
	South Asian (b)	130	3.44 ^c	1.56	3.17	3.71			
	East Asian (c)	128	2.82 ^{bd}	1.49	2.56	3.08			
	Black (d)	130	3.47 ^c	1.60	3.19	3.74			
Negative deactive affect	White (a)	132	3.22	1.62	2.95	3.50	3	4.33	.005
	South Asian (b)	130	3.63 ^c	1.59	3.35	3.90			
	East Asian (c)	128	3.11 ^{bd}	1.60	2.83	3.39			
	Black (d)	130	3.71 ^c	1.63	3.42	3.99			
Extraversion	White (a)	132	2.96	.76	2.83	3.09	3	2.05	.11
	South Asian (b)	130	3.12	.58	3.02	3.23			
	East Asian (c)	128	2.93	.74	2.81	3.06			
	Black (d)	130	3.07	.59	2.93	3.13			
Agreeableness	White (a)	132	3.47	.58	3.37	3.57	3	.61	.61
	South Asian (b)	130	3.52	.58	3.41	3.62			
	East Asian (c)	128	3.57	.53	3.48	3.66			
	Black (d)	130	3.53	.66	3.41	3.64			
Consciousness	White (a)	132	3.54	.64	3.43	3.66	3	2.02	.11
	South Asian (b)	130	3.51	.64	3.40	3.62			
	East Asian (c)	128	3.51	.63	3.40	3.62			
	Black (d)	130	3.36	.67	3.25	3.48			
Emotional instability	White (a)	132	2.98	.74	2.85	3.11	3	.95	.41
	South Asian (b)	130	3.02	.60	2.92	3.12			
	East Asian (c)	128	2.89	.75	2.76	3.02			

Openness	Black (d)	130	2.92	.72	2.79	3.04	3	4.63	.003
	White (a)	132	3.24	.57	3.14	3.34			
	South Asian (b)	130	3.41 ^c	.49	3.32	3.50			
	East Asian (c)	128	3.22 ^{bd}	.53	3.13	3.31			
	Black (d)	130	3.40 ^c	.54	3.30	3.49			

Note. a, b, c, or d = significantly different from the other group with the corresponding letter as indicated by Tukey's post hoc tests.

8 **Table 3.** *Correlations between main study variables.*

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1) State anxiety	-															
(2) Generalised anxiety	.63***	-														
(3) Depressive symptoms	.70***	.74***	-													
(4) Social anxiety	.38***	.50***	.45***	-												
(5) Shyness	.39***	.36***	.43***	.62***	-											
(6) Self-esteem	-.57***	-.53***	-.56***	-.49***	-.56***	-										
(7) Reappraisal	-.27***	-.12**	-.16***	-.16***	-.17***	.40***	-									
(8) Suppression	.01	.19***	.13**	.18***	.19***	-.10*	.28***	-								
(9) Positive active affect	-.43***	-.18***	-.25***	-.13**	-.27***	.38***	.46***	.21***	-							
(10) Positive deactive affect	-.61	-.38***	-.42***	-.26***	-.27***	.52***	.48***	.18***	.67***	-						
(11) Negative active affect	.36***	.50***	.53***	.38***	.24***	-.36***	-.03	.18***	.12**	-.13**	-					
(12) Negative deactive affect	.46***	.55***	.58***	.42***	.28***	-.42***	-.07	.19***	-.04	-.28***	.78***	-				
(13) Extraversion	-.23***	-.09*	-.16***	-.35***	-.60***	.37***	.29***	-.11**	.40***	.26***	-.001	-.08	-			
(14) Agreeableness	-.23***	-.27***	-.29***	-.27***	-.19***	.32***	.33***	-.01	.13**	.27***	-.36***	-.35***	.14***	-		
(15) Conscientiousness	-.32***	-.35***	-.44***	-.41***	-.35***	.50***	.27***	-.07	.12**	.32***	-.43***	-.42***	.19***	.58***	-	
(16) Emotional instability	.59***	.56***	.61***	.47***	.56***	-.65***	-.28***	.06	-.30***	-.39***	.36***	.42***	-.35***	-.40***	-.49***	-
(17) Openness to experience	-.14**	-.02	-.04	-.16***	-.24***	.30***	.37***	.12**	.34***	.28***	-.02	-.04	.42***	.27***	.26***	-.20***

9 Note. * $p < .05$. ** $p < .01$. *** $p < .001$.

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11 **Table 4.** *Emotion identification from animated videos.*

	White Female Animations		White Male Animations		Asian Female Animations		Asian Male Animations		Black Female Animations		Black Male Animations	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Happiness	7	1.3	4	.8	5	1.0	7	1.3	6	1.2	6	1.2
Sadness	18	3.5	30	5.8	39	7.5	68	13.1	29	5.6	30	5.8
Anger	211	40.6	211	40.6	99	19.0	82	15.8	212	40.8	252	48.5
Pain	41	7.9	48	9.2	76	14.6	111	21.3	37	7.1	36	6.9
Fear	11	2.1	11	2.1	18	3.5	10	1.9	14	2.7	16	3.1
Disgust	215	41.3	203	39.0	267	51.3	224	43.1	200	38.5	165	31.7
None	17	3.3	13	2.5	16	3.1	18	3.5	22	4.2	15	2.9

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14 **Table 5.** Final models from stepwise logistic regression predicting emotion identification (0 = all
15 other emotions; 1 = pain) from facial animations.

Predictor	B	S.E.	Wald (df)	Sig.	Exp(B)	95% C.I.	
<u>Model White female animation¹</u>							
Positive active affect	.17	.10	2.68 (1)	.10	1.18	.97	1.45
Positive deactive affect	-.20	.11	3.24 (1)	.07	.82	.66	1.02
Negative active affect	.18	.07	6.59 (1)	.01	1.20	1.04	1.38
Constant	-1.74	.43	16.00 (1)	<.001	.18		
<u>Model White male animation²</u>							
Ethnicity			8.65 (3)	.03			
South Asian vs. White	.77	.29	7.02 (1)	.01	2.16	1.22	3.83
East Asian vs. White	.12	.31	.16 (1)	.69	1.13	.61	2.08
Black vs. White	.33	.30	1.16 (1)	.28	1.38	.77	2.50
Positive active affect	.16	.07	5.68 (1)	.02	1.17	1.03	1.34
Constant	-1.78	.30	34.83 (1)	<.001	.17		
<u>Model Asian female animation³</u>							
Ethnicity			8.05 (3)	.05			
South Asian vs. White	.72	.28	6.70 (1)	.01	2.06	1.19	3.56
East Asian vs. White	.35	.29	1.47 (1)	.23	1.42	.81	2.49
Black vs. White	.13	.29	.21 (1)	.65	1.14	.65	2.02
Depressive symptoms	.27	.15	3.45 (1)	.06	1.31	.99	1.74
Positive active affect	.23	.07	12.07 (1)	<.001	1.26	1.11	1.44
Constant	-2.45	.51	23.48 (1)	<.001	.09		
<u>Model Asian male animation⁴</u>							
Positive deactive affect	.14	.07	4.82 (1)	.03	1.15	1.02	1.31
Constant	-1.26	.32	15.82 (1)	<.001	.29		
<u>Model Black female animation⁵</u>							
Ethnicity			1.65 (3)	.01			
South Asian vs. White	1.14	.43	7.23 (1)	.01	3.14	1.36	7.23
East Asian vs. White	1.59	.61	6.77 (1)	.01	4.89	1.48	16.16
Black vs. White	2.53	.80	9.96 (1)	.00	12.53	2.61	60.19
State anxiety	-.54	.19	7.88 (1)	.01	.58	.40	.85
Shyness	.47	.23	4.27 (1)	.04	1.60	1.02	2.49
Extraversion	.41	.22	3.51 (1)	.06	1.51	.95	2.32
Agreeableness	-.15	.07	4.48 (1)	.03	.86	.75	.99
<u>Model Black male animation⁶</u>							
Generalised anxiety	.78	.19	16.29 (1)	<.001	2.19	1.50	3.21
Negative deactive affect	-.23	.09	6.25 (1)	.01	.79	.661	.95
Conscientiousness	-.86	.23	14.49 (1)	<.001	.42	.27	.66
Emotional instability	-.80	.23	12.05 (1)	<.001	.45	.29	.71
Constant	2.91	1.19	6.01 (1)	.01	18.44		

16 Note. ¹Model fit: $\chi^2 = 13.77$, df = 3, p = .003; Hosmer & Lemeshow $\chi^2 = 08.07$, df = 8, p = .43; Cox and Snell $R^2 = .03$;
17 Nagelkerke $R^2 = .04$. ²Model fit: $\chi^2 = 15.89$, df = 4, p = .003; Hosmer & Lemeshow $\chi^2 = 6.98$, df = 8, p = .54; Cox and
18 Snell $R^2 = .03$; Nagelkerke $R^2 = .05$. ³Model fit: $\chi^2 = 23.78$, df = 5, p = <.001; Hosmer & Lemeshow $\chi^2 = 2.41$, df = 8, p =
19 .60; Cox and Snell $R^2 = .05$; Nagelkerke $R^2 = .06$. ⁴Model fit: $\chi^2 = 4.92$, df = 1, p = .03; Hosmer & Lemeshow $\chi^2 = 12.88$,
20 df = 8, p = .12; Cox and Snell $R^2 = .01$; Nagelkerke $R^2 = .01$. ⁵Model fit: $\chi^2 = 22.73$, df = 7, p = .002; Hosmer &
21 Lemeshow $\chi^2 = 5.71$, df = 8, p = .74; Cox and Snell $R^2 = .04$; Nagelkerke $R^2 = .07$. ⁶Model fit: $\chi^2 = 32.32$, df = 4, p =
22 <.001; Hosmer & Lemeshow $\chi^2 = 7.17$, df = 8, p = .52; Cox and Snell $R^2 = .06$; Nagelkerke $R^2 = .10$.

23 **Figure 1.** Screen shots of videos showing animated female and male White, Black, and Asian faces expressing highly intense pain.

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Figure 2. Heat maps showing probabilities of expression identification from facial animations (sorted based on low to high probability of pain identification).