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Facial expression of pain: An evolutionary account

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Abstract: This paper proposes that human expression of pain in the presence or absence of caregivers, and the detection of pain by observers, arises from evolved propensities. The function of pain is to demand attention and prioritise escape, recovery, and healing; where others can help achieve these goals, effective communication of pain is required. Evidence is reviewed of a distinct and specific facial expression of pain from infancy to old age, consistent across stimuli, and recognizable as pain by observers. Voluntary control over amplitude is incomplete, and observers can better detect pain that the individual attempts to suppress rather than amplify or simulate. In many clinical and experimental settings, the facial expression of pain is incorporated with verbal and nonverbal vocal activity, posture, and movement in an overall category of pain behaviour. This is assumed by clinicians to be under operant control of social contingencies such as sympathy, caregiving, and practical help; thus, strong facial expression is presumed to constitute an attempt to manipulate these contingencies by amplification of the normal expression. Operant formulations support skepticism about the presence or extent of pain, judgments of malingering, and sometimes the withholding of caregiving and help. To the extent that pain expression is influenced by environmental contingencies, however, "amplification" could equally plausibly constitute the release of suppression according to evolved contingent propensities that guide behaviour. Pain has been largely neglected in the evolutionary literature and the literature on expression of emotion, but an evolutionary account can generate improved assessment of pain and reactions to it.

Keywords: adaptation; evolutionary psychology; facial expression; pain

The insights provided by the application of evolutionary psychology to established fields of evidence has clinical relevance in areas such as fears, anxiety, and depression (Dimberg & Ohman 1996; Gilbert 1992; Marks & Nesse 1994). Certain evolved behaviours, such as the attachment behaviour of human and other primate infants, are accepted as orthodoxy. But broader notions of an evolved "human nature," that is, of specialised propensities[1] that generate functional behaviours effective in the social and material world, are still viewed with skepticism or indifference by many in the psychological and medical communities (Andersson 1993; Schaffner 1998). Among the more important reasons for this may be concern about genetic determinism or, at least, a distaste for invoking genetic factors (Crawford 1989; Daly & Wilson 1988; Plomin 1989; Tooby & Cosmides 1992), and suspicion of "Just-So Stories," that is, post hoc explanations from available evidence (Gould & Lewontin 1979). Far from endorsing the over-simple gene explanations that are sporadically revisited in psychiatry (Plomin 1989), evolutionary psychology aims to broaden our understanding of behaviour, in all its flexibility and contingency in relation to the immediate environment and the individual's learning history, by addressing the cognitive adaptations that are part of our heritage (Cronin 1991).

1. The function of pain

Pain is the "final mediator" of a wide range of selection pressures (Walters 1994): sublethal injuries that may still threaten survival or reproduction are incurred during predation, intraspecific combat, and competition with conspecifics. By virtue of its aversiveness, pain serves to promote the organism's health and integrity, to the extent that congenital absence of pain on injury significantly shortens human life (Damasio 1999; Wall 1999): "Suffering offers us the best protection for survival" (Damasio 1994, p. 264). The adaptive value of experiencing pain at first seems self-evident: distinguishing harmful from harmless situations, prompting avoidance of harm and its associated cues, giving a high priority to escape from danger, and promoting healing by inhibiting other activities that might cause further tissue damage (Bateson 1991). Research in animals has focussed mainly on immediate escape from pain (e.g., Rachlin 1985), but according to Wall (1979; 1999), this is

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less important than making recovery the overriding priority after escape. The presence and intensity of pain are often poorly related to the degree of tissue damage, making it too late for prevention of injury, if not for future avoidance; neither escape nor avoidance would require that pain continued well into the recovery phase, demanding attention and not habituating to any appreciable degree in humans (Eccleston & Crombez 1999). The affective dimension of pain appears to share mechanisms with vigilance to threat (Chapman 1995; Crombez et al. 1998), and threat itself facilitates attention to pain (Eccleston & Crombez 1999).

The gate control theory (Melzack & Wall 1965) brought about a paradigm shift in the study and understanding of pain. It proposed that the pain signal following tissue damage is modulated at each synapse, thus throughout its transmission, by the balance of signals from the periphery and from descending pathways originating in multiple sites in the brain. This allowed for the influence on the signals and their transmission of memories and prior learning; beliefs, fears, and expectations; and emotional state. However, these affective-motivational aspects have been sidelined in subsequent research that has established a great deal more about the sensory-discriminative dimension of pain; for instance, aspects such as its quality, location, and intensity which are largely determined by peripheral input (Chapman & Nakamura 1999; Craig 1999). Although there is debate on the extent of anatomical separation of sensory-discriminative and affective-motivational processing of pain in the brain, there is consensus on the importance of recognising the separate processes (Price 1999; Wall 1999). Clinical and scientific focus, however, remains on pain sensation and sensory discriminative processing, for a number of reasons. Almost all experimental work is performed on animals, with most attention to quantification of nociceptive stimuli and their local effects; some attention to a restricted range of behaviours (largely escape and avoidance); and none to emotion and cognition. Experimental work is largely restricted to acute pain and to peripheral and spinal mechanisms; although brain-imaging techniques offer rich data, its interpretation lacks adequate models (Wall 1999). "The careful sensory neurophysiologist who strays from the spinothalamic pathway quickly becomes lost in a huge and complex maze of reciprocal connections" (Chapman & Nakamura 1999, p. 114).

Although the neurophysiological model performs far better than its predecessors in building an understanding of pain and of methods of analgesia, it casts little light on the evolutionary function of pain and related behaviour. Pain undoubtedly motivates to action (Damasio 1994; Frijda 1994; Hinde 1985; Wall 1999), serving as a "lever" for decision making and for action based on drives and instincts (Damasio 1999). Behaviour following injury shows remarkable consistency across species (Walters 1994), modified by contextual variables such as the nature of the threat, the severity or imminence of injury, its location, and the costs of active defense. On the basis of accumulating evidence about the activity of areas of the brain concerned with motor function, Wall (1999) proposes analysis of pain by synthesis: that sensory inputs are analysed, classified, and identified by premotor systems in terms of motor actions relevant to the input, with the priorities of first escaping the stimulus, then limiting further damage and prioritising recovery, and then seeking safety and relief. However, it is harder to adduce evidence for this from laboratory studies in which possible behaviours are constrained, often conditioned rather than unconditioned, and the widespread use of electric shock as the noxious (but not tissue-damaging) stimulus in research with laboratory animals raises questions of generalisability to injury-related pain (Panskepp et al. 1997; Walters 1994). Outside the laboratory, there is a dearth of observations of the behaviour of wounded mammals (Fleckness & Molony 1997; Mench & Mason 1997; Walters 1994), and what observations exist rely on the interpretation of behaviour or changes in behaviour whose function is not fully understood (Mench & Mason 1997). Assessment methods for pain in domesticated and farm animals are unstandardised (Fleckness & Molony 1997). The extent of pain in animals soon after injury, in the escape or active defence phase, is uncertain compared to its presence later on when the animal is resting and protecting the injured area (Wall 1979; 1999). This has led to models, such as those of Bolles and Fanselow (1980) that locate the warning function in the emotional experience of threat and fear in the early post-injury phase.

The emotion (affect) dimension of pain is therefore largely absent from much pain research, but because pain does not fit the paradigm of emotion (Ekman 1992; Izard 1991; Frijda 1994) it falls outside investigation of emotional expression. By contrast, the definition of pain by the International Association for the Study of Pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (IASP 1979) provides a central role for emotion. Outside the pain field it is rare to find pain described other than as an aversive sensation associated with avoidance and escape, even in evolutionary writing on adaptations: for example, Nesse and Williams (1994) describe pain phenomena in humans entirely in terms of design compromises for defence. Imaging of pain processing in humans and clinical lesion studies indicate distinct locations for encoding unpleasantness aspects (in the anterior cingulate) compared to sensory aspects (in the somatosensory cortex) (Damasio 1994; Rainville et al. 1997), and for learned anticipation of pain compared to actual pain (in different parts of the anterior cingulate cortex, the insular cortex, and the cerebellum: Ploghaus et al. 1999). It is noted that all these areas where pain is processed are close to areas involved in motor responses (Ploghaus et al. 1999; Rainville et al. 1997), recalling Wall's model of analysis of pain by synthesis with possible motor responses.

In humans, emotional aspects have largely been investigated by self-report, relying on consciously represented experiences (such as fear) or consciously initiated action (such as coping). The rich literature on cognitive content and processes, including emotion, associated with pain, consists of a bewildering array of associated concepts (such as sense of control, beliefs about illness, coping attempts), few of which bear any reliable relationship either with identifiable cognitive processes or with specific behaviours. By contrast, experimental work on attention and pain (Eccleston & Crombez 1999), which includes methodologies that sample nonconscious processes, complements the motivational model: pain grabs attention, interrupts associated behaviour, and urges action toward mitigating it; the more intense and threatening the pain, the more disruptive of attention to anything else. Considerations of adaptive mechanisms and function of pain are, however, rare in the pain field, with some notable exceptions such as the work of Craig and

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colleagues on facial expression, and of Crombez and Eccleston and colleagues (Crombez et al. 1996; 1998; Eccleston et al. 1997) and Chapman (1995) on cognitive mechanisms and pain. In a broader cognitive context, theoretical models of consciousness that incorporate somatic experience (Chapman & Nakamura 1999; Damasio 1999; Melzack 1999) provide the basis for integration of supraspinal processing of pain, but still tend to under-represent the interaction of thoughts, beliefs, and emotional state with pain (Keefe et al. 1996). An ideal model of pain would extend the ecological validity of the current detailed understanding of neurophysiology and integrate it with behavioural, cognitive, and emotional dimensions. Models developed in human research are diverse, with minimal theoretical integration between them or with sensory experimental work (although cognitive and behavioural models are often combined in treatment), and very little reference to function in evolutionary terms. Some of those who have attempted integrated theories note that they struggle against the bias in language (Sullivan 1995) and pervasive dualism (Chapman 1995; Morris 1998).

A major psychological model that has dominated pain psychology in clinical settings for several decades is the operant model proposed by Fordyce et al. (1968) described more fully below. Although it is a theory of pain behaviour rather than of pain, and explicitly builds on the gate control model of pain, it is important because – consistent with Skinnerian behaviourist principles – it asserted that pain was unknowable, and that the proper focus of theory and empirical work was observable and quantifiable behaviours associated with pain (henceforth "pain behaviours"). In the course of repeated episodes of pain, or with persistent pain, unconditioned verbal, paraverbal, and motor responses come under the control of external contingencies. These behaviours contribute to or constitute aspects of disability. Support for the concept was largely drawn from its behavioural origins, specifically from positive associations of frequencies of pain behaviours with availability of social reinforcement, and from accounts of treatment (Fordyce et al. 1968; 1981; Sternbach 1968). However, there are relatively few tests of the covariation of pain behaviours with social and instrumental reinforcement (Keefe & Dunsmore 1992; Turk & Matyas 1992), and clinical practice rarely establishes by observation the contingent relationships of behaviours targeted in treatment. Instead, the availability of potential social reinforcement is taken to support the likelihood that pain behaviours observed in clinical settings are operantly controlled. It seems to be widely overlooked that many pain behaviours such as vocalisation of distress, guarding, limping, and avoiding activity, are shared with many other species in acute and chronic pain where there is no suggestion that they are actually under operant control, although in some circumstances certain behaviours can be so manipulated.

Behaviourism aims to deduce the working of the mind from behaviour, but in the field of pain, the external contingencies whose balance and likelihood determine the frequency of behaviour become, by oversimplification and in the absence of a theory of motivation, the reasons for that behaviour. It has, however, contributed to the development of an interactional and socially contextual formulation of pain behaviour. Cognitive theory in pain represents behaviour as driven by beliefs and their emotional tone (such as the fear-laden certainty that the processes causing pain threaten physical integrity); expressive behaviour is conceptualised as an epiphenomenon of internal experience, or more often left to behavioural explanations. By contrast with behaviourism, evolutionary psychology aims to understand behaviour through a theory of mind, incorporating cognitive, emotional, and motivational dimensions. Its focus is "behavioral control mechanisms [that] are organized to process adaptively significant information and respond thereto" (Daly & Wilson 1991, p. 163). But the two perspectives do not necessarily provide contrasting predictions of observed behaviour. Environmental influences, from cultural norms to interactions with particular individuals, act on behavioural tendencies that are, already, the outcome of contextual propensities to action, with reference to the balance of costs and benefits (for the future of the individual's genes, not the individual) of possible behaviours in a particular situation. Where possible, descriptions generated by behavioural and evolutionary theories are contrasted, but at this stage of development of the theory, no opposing hypotheses are put up for test. The challenge is not to all application of behavioural theory to the field of pain behaviour, but to its weakness in explaining such behaviour particularly in clinical setting, and to its shortcomings in relation to the interactive nature of pain expression, as in the systematic biases evident in certain observer judgments of pain.

This paper first addresses in greater detail the unsatisfactory aspects of the global pain behaviour construct to describe clinically relevant behaviours, particularly those that affect clinical decisions and pain sufferers' well-being. It then sketches the tenets of evolutionary psychology applied to propensities for behaviour and the function of that behaviour. Germane areas of work include that of facial expression of emotion, as proposed by Prkachin (1997), and particularly the work of Ekman and colleagues and of Fridlund. These are then applied to the evidence on facial expression of pain, studied systematically, and with close reference both to theory and to clinical dilemmas, by Craig and LeResche and their colleagues. Although these researchers make reference – particularly in work on infants' expression, in consistency of expression (Prkachin 1992b), and in reviews of the field (Craig et al. 1992; LeResche & Dworkin 1984) – to a communicative facial expression as the product of evolution and as a cue for help-giving (Anand et al. 1999; Prkachin et al. 1983), their research questions have not primarily been informed by evolutionary psychology. Their studies constitute an invaluable canon in the field largely overlooked by those studying facial expression of emotion, and this article relies substantially on their findings, reinterpreted in a broader context. The major issues are the extent to which facial pain expression, wittingly or unwittingly, constitutes a reliable communication of pain; the factors influencing suppression and amplification; the issue of simulation of pain expression; and detection and the biases affecting observer judgment. This article concludes with areas of particular difficulty for the approach such as application in chronic pain, ecological validity of methodology, and some clinical issues that urgently require addressing.

However, this article comes with a warning. Of major concern to the author and to colleagues in the pain field is the risk that description of an evolved pain expression in acute pain might be mistaken as offering a tool for distinguishing "real" from "faked" or "imagined" pain across all circumstances. The patient as an unreliable reporter of verifiable internal events is blamed when the two do not correspond, often resulting in treatment failure (Armstrong 1984). Psychoanalytic, personality, psychopathological, and humanistic schools of psychology provide models that share with psychiatry certain dualistic assumptions about deviant expression of unmet needs through the unverifiable complaint of pain. Similar misconstructions, to the considerable detriment of patients, of behavioural signs of distress as pathognomic of malingering arose following the publication of work describing physical manoeuvres that indicated patient distress rather than pain intensity (Waddell et al. 1980). This article emphatically cannot provide a means of identifying intentional simulation of pain.

2. Pain behaviour

Variants of the operant model are barely represented in the pain field, which has developed with considerable consistency from the original propositions by Fordyce (1976). Pain behaviours are by definition observable, and many of the contingencies for pain behaviours consist of social reinforcement such as sympathetic attention or help, but can also be the socially sanctioned avoidance of unpleasant events such as burdensome duties (Fordyce 1976). This model identified as targets for treatment both the pain behaviours and their governing contingencies. For example, the patient whose pain elicited the sympathy of family members only when he drew attention to it, found that attention withdrawn and given instead when he communicated about other things than about his pain. Several experimental and clinical studies provide evidence of change in the frequency of pain report (Block et al. 1980; Flor et al. 1995; Linton & Gotestam 1985; White & Sanders 1986) and in observed activity (Flor et al. 1987a; Ritchie 1976) in relation to actual reinforcement, or the presence compared to the absence of a source of social reinforcement. Although these studies may explain substantial variance in the maintenance of one or more pain behaviours, and possibly, the production of those behaviours in a social setting, we can deduce little about etiology or function of these behaviours. By contrast, two studies found a substantial proportion of variance in pain behaviour during medical examination to be attributable to medical findings such as number of previous surgeries or limitation of joint movement (Keefe et al. 1984; Novy et al. 1996), and several attempted replications or part-replications of the study by Block et al. (1980) have produced results inconsistent with operant predictions (Lousberg et al. 1992; Paulsen & Altmaier 1995; Williamson et al. 1997).

More broadly, by design there was no place for emotion within the model, nor for cognitive content or process in generating or moderating behaviour, although learning history was identified as an influence on current behaviour. With the growth of cognitive psychology, within and outside the pain field, the associations between cognitive variables such as beliefs and expectations, emotions such as fear and distress, and behaviours including pain behaviours, are under investigation. The importance of escape and avoidance when threatened with increasing pain are now revisited in a cognitive-behavioural formulation (Vlaeyen & Linton 2000). Of particular importance are vigilance to threatened injury or reinjury, sustained through the recovery period (Walters 1994), and fear-laden beliefs about threat and risk, which bias interpretation of ambiguous stimuli (such as increased pain or associated symptoms) and maintain vigilant attention to pain-related cues (Craig 1999; Vlaeyen & Linton 2000).

The concept of pain behaviour and its use have been subject to criticism (see, e.g., Keefe & Dunsmore 1992; Melzack 1985; Turk & Matyas 1992; Wall 1985), including the neglect of possible adaptive properties of various pain behaviours (Turk & Matyas 1992), but this has not had the impact it merits on the theory and investigation of pain behaviour. Despite the diversity of pain behaviours (verbal complaint; vocal, facial and postural behaviour; and particular activities or their avoidance) suggesting differences in function (Prkachin 1986; 1997), treatment and correlational studies generally represented pain behaviour as a unidimensional construct. Facial expression is the exception to this tendency, and excellent and detailed studies of facial expression of pain allow re-examination of the data using an evolutionary perspective. The relationship of facial expression to other behaviours remains unexplored in pain. Other behaviours, although they may augment or modify the message in the face (Argyle 1988), may have other functions: cancer patients who viewed their videotaped behaviour in the presence of a spouse (Wilkie & Keefe 1991; Wilkie et al. 1992) mainly explained it as attempts to reduce pain (e.g., by rubbing or support), or to control the display of pain to attain superordinate goals such as remaining active or not embarrassing others.

For observers, pain as a symptom presents particular difficulties, the more acute when, like clinicians, the observers must make a judgment and decision based on their observation, because the problem presented may consist entirely of self-report. There may be no consistent or proportional evidence for a pain problem from other sources such as clinical signs or investigations, because the changes are in neurophysiological function rather than anatomical structure, as described earlier. Many injury-related pains outlast healing; others are not attributable to injury, as in much headache, visceral pain, and neuropathic pain. One of the strengths of research on pain behaviour is that it addresses the difficult issue of skepticism of observers about the credibility of pain, almost completely neglected by other psychological perspectives. Observers generally trust nonverbal expression more than self-report (Craig et al. 1992; Poole & Craig 1992). All behaviour is influenced by social context: The important distinctions for the complaint of pain are between subjective pain experience and its observable expression, and between influences on behaviour arising from learned contingencies of response but not represented in conscious experience, and the conscious and deliberate intention to manipulate those responses by particular behaviours. For example, an influential paper by Waddell and colleagues (1980), which identified five signs on physical examination any three of which indicated distress worthy of psychological assessment, described one of the signs as "overreaction during examination" which "may take the form of disproportionate verbalization, facial expression, muscle tension" (p. 119). Unless the physical examination is always conducted below the threshold of pain, which rather vitiates its purpose, some facial expression of pain is likely to be observed. It is interesting that of the five signs, this was the most influential in surgeons' judgments, even though it was the most subjective; and that contrary to the authors' expectations, these signs failed to distinguish patients with medicolegal or compensation cases (i.e., with the prospects of gain from the judgment that they had severe pain) from those without.

Although operant formulations did not generally equate pain experience with pain behaviour (Fordyce et al. 1985), they directed attention towards presumed social and material benefits of being observed to be in pain (such as family and medical attention, compensation and disability payments, and suspension of onerous duties) and away from the costs and losses of being in pain, of more interest to those who studied subjectivity and emotion. The explanation of patients' behaviour – the complaint of pain and unwillingness to resume normal activities – by reference to assumed benefits is adopted widely in clinical medicine, as an apparently scientific way to express skepticism, and as a way to explain the lack of association between the patient's complaint and the lack of confirming medical evidence that is common in chronic pain.

The fact that facial expression conveys information does not necessarily imply either conscious control before or during the expression, or intentional signaling. Unfortunately, definitions of pain behaviour, including facial expression, tend to use ambiguous terminology, which may appear to describe deliberate communication: "The observable phenomena of pain consist essentially of some kind of *signal sent by the patient* that he is in pain" (Fordyce et al. 1968, p. 179, emphasis added); the "observable means of communicating pain and suffering" (Turk et al. 1985). The expressive individual may or may not be aware of this communication. In fact, the only time we can be certain that expression is intentional is when it is posed, with or without the associated experience, under instruction.

As described in the first section of this article, operant mechanisms act on unconditioned pain behaviours. But where the implicit assumption is of a *tabula rasa* at birth, operant mechanisms become the exclusive explanation for pain, invoked with minimal or no evidence. Prkachin et al. (2001) comment critically on the wealth of speculation about family members' potential influence on the development of pain compared to the dearth of hypotheses or studies of how family members actually process pain information. The lack of research, even in animals, on unconditioned pain responses, contributes to this bias in the field. It remains to be seen whether definitive tests can be designed where the processes can be observed working separately or together. None of the studies reviewed in this paper were undertaken with the intention of distinguishing between contrasting predictions. Nor do any do so coincidentally, other than the experimental finding that subjects show more facial expression of pain when alone, than when they believe themselves observed (Kleck et al. 1976) or are observed by neutral strangers (Badali 2000): In the latter study, self-report showed the same bias, but tolerance to pain was the same across situations. At times, predictions by different models coincide, for example, in anticipating that the person in pain will show more vivid expression of pain, whether through the release of suppression of pain expression in the presence of someone identified as a help-giver (evolutionary explanation), or on the basis of previous reinforcement of the expression by that person or class of persons (operant explanation).

Nevertheless, this article reviews evidence collected in the investigation of facial expression of pain in the light of evolutionary theory. To varying extents in the different areas, evolutionary theory provides a superior explanation, or provides one where operant theory is silent. The theory of evolved pain expression predicts a distinct and specific expression of pain, across the lifespan, across pain stimuli, and across cultures. By contrast, operant theory would anticipate pain expression shaped by contingencies that might be specific to cultures and life stages. Although evolved pain expression can be proposed only in the context of co-evolution of its accurate detection by observers and its interpretation in terms of approximate severity, there is no literature on the operant processes by which accurate detection would be learned, and, again, it could be culture-specific. In evolutionary terms, the ability to suppress pain expression would potentially be of survival advantage (as when hiding pain from antagonists); but for the observer, whether ally or antagonist, the ability to detect pain expression despite attempts to suppress it would potentially have survival advantage. The position is not so clear for the ability to amplify or simulate pain expression: Although it might bring advantages for the individual in pain but at a fairly trivial level of successful social cheating, for the onlooker, the ability to detect that pain has been amplified, or simulated in its absence, could have important implications for spending of precious resources. Operant theory would make far stronger predictions about amplification and simulation: On the assumption that more often than not pain expression brings benefits, the ability to simulate and amplify would be rewarded, unlike the ability to suppress. Again, it is not clear what operant theory would predict for the observer's detection of amplified and simulated pain expression.

3. Evolutionary psychology

An account is proposed that draws on evolutionary studies of social behaviours. Certain pain behaviours, or rather the propensities that underlie them, are likely to have been subject to natural selection insofar as they conferred advantage on the individuals who used them, across contexts from the presence of potential help-givers to that of known antagonists. Of necessity, vigilance to observed pain cues in others coevolved. The individual expressing pain would derive benefit if expression of pain were reliably followed by actions by observers that promoted recovery and survival; protection from danger; and aid in obtaining basic requirements (Prkachin 1997; Prkachin et al. 1983). If the person in pain might survive rather than not, and the cost to helpers is low, selection advantage follows as with other help and exchange of information – the currency of kin or reciprocal altruism. Although the exploitation of others' help achieves maximum payoff in a single encounter, individuals' sensitivity to possible "social cheating" (i.e., to the other taking a benefit without paying the costs) protects them from repeated exploitation over a series of interactions (Cosmides & Tooby 1992; 1997). The following paragraphs expand this hypothesis and review supporting evidence.

Recent development of evolutionary theory in the light of genetics (neo-Darwinism) combines Darwin's understanding of selection pressures with their application at a genetic level, not on the individual or group (Dawkins 1976). Selection operates at the level of function, not at the level of physical structures or behaviours that subserve the function. "Fitness is not a psychological goal. Psychological mechanisms have evolved as a means to the end of fitness in the social and material environment of evolutionary adaptation" (Daly & Wilson 1991, p. 164). One or more genes may be expressed in complex contingent behaviours dependent on contextual variables, including the frequencies of alternative behaviours, or alternatively as universal ("fixed") phenotypes, in which case no variation is evident now. Applied to psychology, this has led to the study of cognitive and behavioural routines as "innate, specialized learning mechanisms that organize experience into adaptively meaningful schema or frames" (Crawford 1989, p. 16). Such mechanisms are likely to be specific rather than general (Tooby & Cosmides 1990), and related to environmental demands, threats, and challenges in that they "focus attention, organize perception and memory, and call up specialized knowledge required for domain-appropriate inferences, judgments, and choices. In the context of life history theory, they are mechanisms that mediate environmentally contingent tactics by processing information" (Crawford 1989, p. 16). Skinner likened evolution by natural selection to learning by trial and error (Maynard Smith 1995): Success is defined as an increase in the frequency of the target outcome. Behaviours that promote survival and/or reproductive advantage thereby maximise the likelihood of passage of their owner's genes to the next generation: Selection shapes bodies and minds to the conditions within which they exist (Daly & Wilson 1988). So proposed rules must be tested not against an apparent fit between current behaviour and environment (Tooby & Cosmides 1992), but to the presumed ancestral environment(s) and probable variations in behaviour, perceptions, or propensities.

What criteria can be used to address the suggestion that a behavioural routine results from natural selection of an underlying propensity? Selection advantage relies on benefits outweighing the cost incurred by any action, so a convincing case must be made for those benefits, as in the detection of fear. That, in turn, requires that the behaviour itself is specific, and that it is detected and interpreted by others. Tooby and Cosmides (1990; 1992) proposed further criteria required to support the claim that a behaviour, or rather the propensity governing it, was an evolved adaptation: the specification of process and mechanisms by which a change in the frequency of the characteristic in the population could occur; a task analysis of problems in the ancestral environment that were solved by the adaptation; a description of the adaptation in terms of mechanisms or algorithms, rather than behaviour; and, where possible, an analysis of how the adaptation is manifest under current conditions where they differ from the ancestral environment.

These criteria are addressed here with reference to facial expression in general terms, with further detail on pain facial expression later. The same selective pressures toward better communication between group-living prehumans and humans, which brought about the development of language (Pinker 1994), would have operated for conveying information by nonverbal means, including facial expression (Fridlund 1994). Altruism to genetic kin in proportion to their kinship (Williams 1966) and reciprocal altruism, the exchange of help over repeated encounters to the benefit of both parties (Hamilton 1971/1996; Trivers 1971), explain help-giving in terms of adaptation. The latter has been developed as a social contract theory (Cosmides & Tooby 1992) of psychological adaptations for mutually beneficial and reciprocal exchanges. This can be sustained only if both parties in the exchange are alert to defaulting (social cheating): to taking a benefit without paying the cost (reciprocation or exchange), or without being entitled to it (Cosmides & Tooby 1992; 1997), in which case nonreciprocators are recognised and excluded from help-giving (Cosmides & Tooby 1992; Frank 1988; Hamilton 1971/1996; Tooby & Cosmides 1996). By contrast with exchange-based mechanisms, a further adaptation concerned with the giving and receipt of help is the cultivation of friendship and irreplaceability within close social groups (Frank 1988; Tooby & Cosmides 1996), such that when a member of that group is in dire need (and for the same reason unlikely to be able to reciprocate), others' stake in the needy individual's survival ensures their attempts to help. Reliable communication clearly provides the means for such adaptations to evolve.

The "problem" to which facial expression of pain is suggested as a solution is twofold, concerning benefits to the signaller and to the onlooker. In certain cases, these differ for immediate response to threat of pain or pain on injury and for the responses during the recovery phase, but it would be mistaken to imply that these are entirely separate because the recovery phase is punctuated by acute pains, related to necessary movement, body functions, or pathological processes at the injury site.

The benefit to allies who receive information about potential danger is exemplified by the countless examples across species of alarm calls; and in humans and some primates, vicarious learning from fear signals of conspecifics has been well demonstrated (Mineka & Cook 1993; Vaughan & Lanzetta 1980). Information is of value for safety and survival, because in any set of circumstances there are many possible courses of action, but few are beneficial (Tooby & Cosmides 1990). Although there are exceptions, where information about painful danger is not specific enough for subsequent avoidance (e.g., slow-developing inflammatory responses), attention to cues associated with pain would generally be advantageous. There are also likely benefits to an antagonist competitor or predator in detecting pain in the other, to press advantage by a variety of means. Over the longer time frame of recovery, the benefits and costs to the friendly onlooker are best described within the framework of help relationships described; there is no separate case to be made for the antagonist onlookers in the recovery phase because this situation returns that of immediate threat.

Benefits to the signaller in pain are more varied and uncertain, and must be set against the resource costs of signalling and the possible risk of increasing vulnerability. For the individual in pain and under threat, or during recovery, who expressed pain in the presence of observant allies, help and protection rendered could be crucial for survival. The skeletons of Neanderthals (200,000 years ago) and those of Homo erectus and early Homo sapiens (around 100,000 years ago) show healed major bone fractures (Hamilton 1971/1996; Mithen 1996; Pinker 1994), compatible with receiving help from other humans while the injured party could not fend for him- or herself. For the individual in pain in the presence of antagonists, the acute expression of pain might disclose weakness and increase vulnerability, to the cost of the individual in pain. Such a disclosure could also initiate a negotiated withdrawal to safety (Gilbert 1992), with obvious benefits for the individual's survival.

Various selection pressures on the individual's capacity both to exert voluntary control over the amplitude of facial expression (suppression and amplification), and on the capacities of observers to identify pain and its approximate severity despite those attempts, can be posited for the injured individual and for his or her allies and antagonists. Although facial expression does not require consciousness on the part of the signaller to communicate a message to onlookers, consideration below (sect. 4) focuses mainly on the conscious modulation of the facial expression of pain, because that is where empirical evidence is concentrated. It extends as far as is possible towards the formulation of behavioural patterns and information processing considerations. The interesting field of reflexive aspects of facial expression (facial feedback), that is, of change of subjective and physiological measures in relation to voluntary modification of pain facial expression (Ekman 1993; Lanzetta et al. 1976), is not covered because of the lack of research in pain.

At least partial control for the individual in pain over the amplitude of his or her pain expression allows strategic use of the signal; the ability of the observer to make at least crude distinctions between degrees of pain, without any specific information being added, is also advantageous. The individual in pain might gain both by amplifying pain expression better to convey need to allies, and by suppressing pain expression to hide vulnerability in the presence of antagonists. Simulation of pain in its absence may represent a different signal and require other explanations than those that apply to amplification, or it may be an extension of it. Unfortunately, few studies of simulation have been carried out. For their part, group-living allies need to detect pain in any one of their members when survival of all depends on the effectiveness of each. Antagonists benefit from information about another's pain despite attempts to suppress it, whether they press the advantage or withdraw. Construction of the likely advantages and disadvantages of simulation of pain are of necessity more speculative. The benefit for the individual in being able to simulate pain convincingly may lie in the receipt of help, in the chance to withdraw from the threat of physical damage from an antagonist, or in the possibility of relief from aversive physical tasks. However, humans are alert to social cheating, as described above, of the sort represented by feigning of pain to gain material or tactical advantage, so that in any stable group the simulation of pain would yield rapidly diminishing returns and the withdrawal of help. Costs to the help-giver who believes simulated pain to be real may be wasted energy expenditure or loss of face; it is less likely to have implications for survival.

4. Facial expression

The major work in the area of facial expression has been that of Ekman and colleagues, active for more than 20 years. Ekman proposed distinct faces expressing distinct "basic" emotions, each of which has a particular adaptive function and whose expression is modified by socially learned "display rules" ("culture-specific prescription about who can show which emotions, to whom, and when": Ekman 1993). Subsequent research has largely supported this proposal, with the strongest evidence for facial expression of happiness, surprise, fear, anger, disgust, and sadness, which show distinctiveness, rapid preawareness onset, brief duration, involuntariness, and automatic appraisal by observers (Ekman 1992). Facial expression is under both cortical and subcortical control (Rinn 1991), although it is mistaken to suggest that "spontaneous" or nonvolitional facial expression is necessarily unaffected by overlearned display rules, and a distinction has been proposed between the degree of modification by display rules and the degree of learning involved in the modification (Matsumoto & Lee 1993). Connections run from the limbic system and neocortex to the facial nucleus, in which musculotopic organisation (over upper and lower facial movement) has been identified (Morecraft et al. 2001). Although the limbic system is involved in facial nerve activity in spontaneous facial expression, its involvement is less well established for posed expressions (Argyle 1988). Further support comes from the evidence that humans perceive emotional expression categorically, although muscular changes in the face occur along continuous dimensions (Etcoff & Magee 1992; Young et al. 1997), like colour perception, where recognition appears to proceed by fit to cognitive categories not excluding distinctions made within categories (Young et al. 1997).

Fridlund's behavioural ecology model (Fridlund 1994) builds on Ekman's work but is more explicit about the role of expression in social negotiation with kin, allies or antagonists (see also Hinde 1985), and thus on the coevolution of observers' attention and interpretation. "The form and intensity of a display, and the alignment of the display with personal resources or intentions, would depend on contextual factors such as common interests, availability of resources, and presence of kin, intruders, or predators" (Fridlund 1997, p. 113). Thus, a "fear" face signals readiness to submit; a "felt" smile readiness to affiliate; a "false" smile readiness to appease. For the observer, both hypervigilance and hypovigilance have potential costs. Vigilance for displays requires sensitivity to them (as in electrophysiological evidence for speech and face recognition), selectivity about particular display components, and skepticism about the meaning (might it be deception, or random noise?). Despite apparent automatic processing of the emotional valence of faces (Stenberg et al. 1998), disparity between the relative ease of identification of posed expressions compared to spontaneous expressions when observers have no context (Motley & Camden 1988) gives some support to the importance of context. Debates on the correct model continue: for example, Russell (1997) emphasises context rather more than Fridlund, proposing that dimensions of pleasure and arousal are used to parse the face, and then specific emotion attributed according to the context and knowledge of the person; whereas Buck (1994) envisages a model combining notions of emotional "readout" and of contextual interpretation.

5. Facial expression of pain

To what extent can work on facial expression of emotion be extended to pain? Fundamental questions concern the extent to which it is a specific expression, whether it is detected by observers, and what are the effects on those observers. Most of the empirical evidence comes from Craig and colleagues, whose research questions only partially coincide with those that would be posed from an evolutionary psychology perspective, so that even robust findings may lead only to tentative conclusions. Further sources of evidence are harder to interpret. Fridlund (1994) uses morphological comparison across species in his study of social smiling, but studies of primate pain expression and its morphology have not been done (Universities Federation for Animal Welfare 1989; National Research Council 1992), and discontinuity in morphology would not disconfirm the hypothesis of an evolved pain expression.

The extent of difference between the acute pain face and chronic pain face is an unanswered empirical question, but the two functions are related and are likely at times to coincide. LeResche et al. (1992) found the frequency of chronic pain patients' facial action units (FAUs) was higher for those with pain of longer duration at baseline and during experimental and clinical pain, and interpreted this as evidence that "pain facial expressions are subject to reinforcement and become more frequent over the course of this chronic pain condition: that is, they are indeed chronic pain behaviors." More systematic observation and ecologically valid studies are urgently needed, although the latter pose considerable ethical challenges. Because the study of facial expression in enduring emotional states is generally neglected (Ekman 1992), no hypotheses can be drawn from this quarter. In this article I have chosen to describe pain expression without making a sharp distinction; it remains to be seen whether it would be better described as comprising related expressions that may often occur as a blend. Although the description above is of the acute (rapidly habituating) pain facial expression, conveying threat and alarm to onlookers, it might also serve to elicit immediate help from allies and those with an investment in the person in pain. The chronic pain face is relatively undescribed, and it is difficult to do so with no painfree baseline for comparison (because the pain is by definition intractable), and also because it is more difficult to isolate from expression of associated emotions. Moreover, even without experimental or clinical manipulation, chronic pain is punctuated by acute exacerbations and it is these that have been investigated experimentally. In these studies, however, chronic pain patients at baseline show some facial activity associated with acute facial expression of pain (using mean data or their own expression on experimentally or clinically produced acute pain: LeResche et al. 1992), but the experimental setting does not represent a situation that is likely to cue soliciting of help, and instead may produce some apprehension about expected pain.

Universality of an expression, across cultures, sex and contexts, is a requirement. But it presents considerable methodological difficulties (Ekman 1994; Izard 1994; Russell 1994), and neither universality of expression, nor cultural difference, constitutes decisive evidence for or against an evolved response, rather than one learned in infancy. Low variance across cultures is most apparent for disgust and fear (Ekman et al. 1987), but represents relatively weak evidence of universality. What evidence there is on universality of pain facial expression is discussed below (sect. 5.4); it is strongest in relation to infantile pain expression. From a related field, congenitally blind children show full facial expression of emotion (Fridlund 1994; Matsumoto & Lee 1993), although this cannot be used definitively to support an innate model of expression because their learning of expression may employ nonvisual channels. Methodological and ethical problems preclude definitive tests. Another possible source of evidence is clinical cases where lesions show the dissociation or association of particular functions or behaviours (Fridlund 1994), but availability of such evidence is largely serendipitous, and interpretation of single cases is fraught with difficulty.

Evidence is reviewed under the headings of distinctiveness, consistency, and the degree of voluntary control. For distinctiveness and voluntary control, both the behaviour of the individual expressing pain, usually using the Facial Action Coding System[2] (FACS; Ekman & Friesen 1978), and the judgment of the observer are explored. A further distinction is made on the grounds of ecological validity between clinical participants and events, and experimental ones. Data are described first from painful stimuli (such as a pain-exacerbating movement) applied to chronic pain patients, or painful clinical procedures applied to infants, both of which might be expected to demand attention and to have meaning, and second from experimental paradigms in which volunteers are subjected to a variety of painful stimuli in the context of negligible personal meaning and considerable control over the situation. Nevertheless, only pain-free volunteers can provide data on simulation where the stimulus for pain intensity is controllable.

5.1. Distinctiveness and specificity: Expression of pain

Darwin (1872/1965) noted specific mouth and eye movements and expression in man in pain: "the mouth may be closely compressed, or more commonly the lips are retracted, with the teeth clenched or ground together . . . The eyes stare wildly as in horrified astonishment, or the brows are heavily contracted." In fact, the morphology of facial expression in relation to pain does not correspond well to this description. Several studies using FACS (Craig 1980; Craig et al. 1992; Prkachin 1992b) identify a combination of facial actions that appear to be specific to pain, which they have largely used in subsequent work, including as a single index (e.g., Prkachin et al. 1994). Core action units (AUs) in adults are brow lowering (corrugator: AU4), cheek raise and lid tighten (both parts of orbicularis oculi: AU6 and 7), nose wrinkle and upper lip raise (both parts of levator labii: AU9 and 10), and eye closing (AU43) (Craig et al. 1992; Prkachin 1992b). It is better described as a fuzzy set than a prototype (Prkachin & Craig 1995); but the formulation of prototypes and variants has been retained here for consistency with more extensively investigated facial expressions of sadness, fear, and anger (Ekman & Friesen 1978), although there is no "pure emotion" referent for any expression. These prototypes and variants are shown in Table 1: As can be seen, some action units are shared within the distinct composite (LeResche 1982; LeResche & Dworkin 1988). This, of course, describes the acute pain face, against baselines of no pain and of chronic pain; like the facial expression of negative emotion, but unlike other measures of pain, the acute pain face habituates rapidly if there is no further pain stimulus (Craig & Patrick 1985).

Facial expression appears to carry unique variance in pain (LeResche & Dworkin 1988; Patrick et al. 1986; Prkachin & Mercer 1989), but there is relatively little data on the extent to which the face encodes a particular component of the pain experience, such as intensity, meaning, or affect. Available data suggest that whereas facial expression is more sensitive to stimulus intensity than is self-re-

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Table 1. *Action units characteristic of acute pain face, and of fear, sadness and anger facial expression*

	1 inner brow raiser	2 outer brow raiser	4 brow lower	5 upper lid raiser	6 cheek raiser	7 lid tighten	9 nose wrinkler	10 upper lip raiser	11 nasol. furrow deepen	12 lip corner puller	15 lip corner depr.	17 chin raiser	20 lip stretch	22 lip funnel	23 lip tighten	24 lip pressor	25 lips part	26 jaw drop	27 mouth stretch	43 eyes closed	54 head down	64 eyes down
Sadness	**x**		**x**		x				x		**x**						x	x			x	x
Fear	**x**	**x**	**x**	**x**									x				**x**					
Anger			**x**	**x**		**x**		x				x		x	**x**	x	**x**	**x**				
Pain			**x**		**x**	**x**	**x**	**x**		x			x				x	x	x	**x**		

x = AU which characteristically occurs with emotion prototypes
x = AU which may occur with prototype and/or variant

port (Patrick et al. 1986), in chronic pain patients it encodes cognitive and emotional dimensions of pain rather than sensory quality (by comparison with self-report; LeResche & Dworkin 1988). In an investigation of baseline, clinically produced and experimentally produced pain in patients with chronic pain of recent and longer term onset, LeResche et al. (1992) found that facial expression of those with longer term pain shared a small amount of variance with anxiety and with a tendency to catastrophise.

More complex associations have emerged with several negative emotions. In a FACS analysis of frequency and intensity of pain and emotion facial expressions before and during the acute pain of venipuncture performed on chronic pain patients, Hale and Hadjistavropoulos (1997) found that the intensity of disgust expression increased on venipuncture with pain expression, whereas happiness expression decreased in anticipation (on swabbing before venipuncture). Overall, pain facial action unit (FAU) frequency and intensity was associated with those of disgust, anger, fear, and a decrease in happiness. The facial expressions of disgust, fear, and anger, plus sadness also occurred with pain expression on FACS analysis of chronic pain patients subjected to painful clinical examination (LeResche & Dworkin 1988), but there was no correlation between pain FAUs and self-reported fear and sadness. Multidimensional scaling of similarity judgments between pain and negative emotion prototype facial expressions showed pain to fall close to sadness and anger, at the opposite end of the axis from fear, surprise, and disgust (Kappesser & Williams 2001). In a study of social influence, facial expression appeared insensitive to tolerance or intolerance to pain modelled by stooges. This contrasted with self-report, behavioural, and some physiological measures that were modified in the direction of the model's behaviour (Craig & Prkachin 1978; Prkachin & Craig 1985).

Infants from 25 weeks' gestation, despite considerable individual variation, show a characteristic pain face (Craig et al. 1993; Grunau & Craig 1987; Lilley et al. 1996; Stevens et al. 1994) consisting of eyes squeezed shut, brows lowered/bulging, deepening of the nasolabial furrow, and open lips, occurring together, with mouth stretched vertically and horizontally and taut tongue. This description applies to infants who are awake at pain onset, with a proportionally lesser response for infants who are lightly or deeply asleep at pain onset (Grunau & Craig 1987); it is more than a spinal reflex (Craig et al. 1988). Facial expression provides the most reliable indicator of pain in the first few months (Hadjistavropoulos et al. 1994; Johnson & Strada 1986), and unlike other behavioural and physiological indicators at that age can be distinguished from responses to other stresses (Izard et al. 1995; Lindh et al. 1997). From 3 years of age, when children are able to indicate pain intensity by verbal and pictorial means, facial expression accounts for up to 65% of variance in their ratings (Breau et al. 2001; Goodenough et al. 1998). In children and adolescents whose cognitive impairment precludes the reliable use of verbal or pictorial pain measures, facial expression appears consistent with painful procedures (LaChapelle et al. 1999; van Dongen et al. 1999).

In summary, the acute pain face encodes intensity and emotional and cognitive dimensions; because pain often occurs with other negative emotions; comparison with facial expression of those emotions requires further convergent findings and a technology to identify blends of facial expression. Despite these methodological limitations, facial action units are generally satisfactory to describe facial expression of pain, with a fuzzy set rather than a prototype as the aim. FACS methods have described a reliably produced expression, across ages and a range of cognitive capacities, but probably with some specifics related to the particular experimental paradigm and stimulus characteristics, a relevant issue given that these are somewhat narrow by comparison with everyday experience.

5.2. Consistency across lifespan

Craig (1980) noted strong consistencies in the morphology of facial pain expression from birth through old age, but sensitive to sociocultural norms and immediate social context (see also Craig et al. 1992; LeResche et al. 1992). The integrated pain response of the newborn shows facial activity in common with child and adult versions (Craig et al. 1988), although the infant and young child may show less differentiation between pain and fear (Bush & Harkins 1991). Development of the expression with age has not been described in detail, but in comparison of infant and adult pain FAUs, it is important to recognise that what matters from an evolutionary point of view is that the infant's expression communicates effectively, rather than that it approximates the adult expression (Anand & Craig 1996). Facial expression of pain appears to be largely spared in cognitively impaired elderly people no longer able to report pain verbally or diagrammatically (Benedetti et al. 1999; Hadjistavropoulos et al. 1996; 1998; 1999; LaChapelle et al. 1999; Porter et al. 1996). The issue of communication of pain by nonverbal subjects has been neglected until recently but is clearly of considerable clinical importance (Anand & Craig 1996).

5.3. Consistency across stimuli

The expression appears largely constant across the different experimental pain stimuli of electric shock, cold, pressure, and ischaemic pain (Prkachin 1992b), as shown in

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Table 2. Intensity and duration of orbital tightening varied with pain intensity across all stimuli, and of levator contraction and brow lowering tended nonsignificantly in that direction. Other frequently produced facial action units (FAUs) are mouth opening (AU25), jaw drop, and horizontal mouth stretch (AUs 26 and 27) often coded together as a unit, and oblique lip pull (AU12). All showed change from baseline for all pain stimuli, but the direction of change was not consistent across stimuli (Prkachin 1992b), and it may be that the properties of certain stimuli evoke particular expressions, as in startle to electric shock (Prkachin 1992b). More than a matter of seconds, even with increasing self-report of pain, the frequency of FAUs diminishes (Craig & Patrick 1985). Acute exacerbation of chronic musculoskeletal pain shows a sufficiently characteristic pain expression for consistent data to emerge (Craig et al. 1991; LeResche & Dworkin 1988; Prkachin & Mercer 1989; Prkachin et al. 1994); under these conditions, moderate relationships have been demonstrated between facial expression measures and verbal pain ratings (Craig et al. 1991) and self-reported disability (Prkachin & Mercer 1989). Whether these would hold for other chronic pains, however, such as visceral and neuropathic pains, remains unexplored, so it cannot be said with confidence that there is a pain expression characteristic of the ongoing pain in chronic pain, insofar as that can be treated as a stimulus. The question presents serious methodological problems, in particular, the lack of comparison condition unless an adequate analgesic is available, which, by definition, is not the case in chronic pain.

5.4. Consistency across cultures

Cross-cultural studies of facial expression of pain have not been published (Ekman 1989; 1993; Prkachin 1992b), as they have for facial expression of emotions by Ekman and colleagues. LeResche and Dworkin (1984) found a common description of pain facial expression across Western cultures but concluded that "research has not yet even begun to address the issues of universality or cultural differences in facial expressions of pain." Many studies of cultural differences in verbal and behavioural expression of pain have been criticised for disregarding within-group variation to reproduce stereotypes (Prkachin & Craig 1995), with little attention to facial expression of pain or its detection. Methodological problems in this area are considerable (Ekman 1994; Fridlund 1994; Haidt & Keltner 1999; Russell 1994; 1995). Not only is it extremely difficult to find cultural groups that have not been exposed to Western faces and expression, by television and film as much as by direct contact, but the need for translation in both directions undermines experimental rigour. The design of studies is bedevilled by the unhelpful counterposition of innate and cultural explanations, such that only the most extreme hypotheses can be disconfirmed. One

Table 2. *Facial action units identified in association with clinical and experimental pain stimuli*

Study	Pain stimulus/ subjects	Measure	4 brow lower	6 cheek raiser	7 lid tighten	9 nose wrinkler	10 upper lip raiser	11 nasol. furrow deepen	12 lip corner puller	14 dimpler	20 lip stretch	24 lip pressor	25 lips part	26 jaw drop	27 mouth stretch	41 lid droop	43 eyes closed	45 blink
Prototype and variants			**x**	**x**		**x**			x		x		x	x	x		**x**	
LeResche 1982	clin./various	pres	**x**	**x**	**x**			**x**			**x**		**x**	**x**	**x**		**x**	
Prkachin & Mercer 1989	clin exam / SP	pres	**x**	**x**	**x**									**x**		**x**	**x**	
LeResche & Dworkin 1988	clin exam / TMJ	freq	**x**	**x**	**x**	x	x				x		x				**x**	
Craig et al. 1991	clin exam/ chronic LBP	freq	**x**	**x**	**x**		**x**						**x**				**x**	
Hadjistavropoulos & Craig 1994	clin moves/ acute & chronic LBP	freq	**x**	**x**		**x**								**x**				
Prkachin & Mercer 1989	clin exam/SP	int	**x**	**x**		**x**			**x**		**x**			**x**				
Hadjistavropoulos & Craig 1994	clin moves / acute & chronic LBP	int		**x**								**x**		**x**				
Prkachin & Mercer 1989	clin exam/SP	dur	**x**	**x**		**x**			**x**		**x**			**x**			**x**	
Wilkie 1995	sit, stand, walk, lie/cancer	pres	**x**	**x**							**x**						**x**	
Patrick et al. 1986	shock	pres	**x**	**x**			**x**											**x**
Craig & Patrick 1985	cold	freq		**x**			**x**		**x**				**x**	**x**	**x**		**x**	
Prkachin 1992	various	freq																**x** −
Galin & Thorn 1993	cold / healthy	freq		**x**					**x**	**x**			**x**					
Prkachin 1992	various	int	**x**	**x**		**x**			**x**									
Prkachin 1992	various	dur	**x**	**x**		**x**			**x** +−								**x**	

x AU which increases; x AU may occur with other AUs; LBP low back pain; − decrease; +− increase or decrease; SP shoulder pain; pres presence; freq frequency; TMJ temporomandibular joint disorder; int intensity; dur duration

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good quality study (Rosmus et al. 2000) used a well-developed neonatal version of FACS, and standard cry analysis, during routine immunization at two months of healthy Canadian born Chinese and non-Chinese babies whose mothers differed as expected in acculturation to a Western lifestyle. Differences emerged in one of seven facial characteristics and two of six cry characteristics on needlestick, with no baseline differences. Despite the careful design, interpretation remains difficult. There are differences in the rate of motor development across populations, and although all babies were alert and awake before immunization the Chinese babies (who reacted more) may have been more aroused as a result of setting differences. Also, the role of culture in infant pain response in general remains unclear.

Overall, the evidence is strongest for a reliable pain expression across the lifespan. Within the limits of experimental conditions, the evidence is good for consistency of facial expression across painful stimuli, in otherwise pain-free or chronic pain subjects. For both, facial action coding systems have proved a very useful tool for analysis of data. The question about similarities and differences across cultures has not been satisfactorily attempted, however, and there are very considerable difficulties in designing a study that is not open to multiple explanations.

5.5. Distinctiveness and specificity: Detection by onlookers

The counterpart of a distinctive and specific expression in the individual is its detection and correct interpretation by observers. Judgment of pain in another person relies heavily on facial cues: brow lowering, eye blinking, cheek raise, and upper lip raise account for more than half the variance in ratings. These are used consistently by observers to judge pain in adults and in children (Craig et al. 1991; Watt-Watson et al. 1990), but with systematic underuse of some cues, even the most common (Hadjistavropoulos et al. 1996; Prkachin et al. 1994). There is evidence of reasonably accurate identification of pain expression in adults and infants using the specific facial movements described above (Breau et al. 2001; Goodenough et al. 1997; Lilley et al. 1996; Lindh et al. 1997; Prkachin et al. 1994), but the data on distinction of pain in adults and children from other facial expressions, such as those of fear or anger, are scant (Boucher 1969; Hale & Hadjistavropoulos 1997; Huebner & Izard 1988; Kappesser & Williams 2001; Keltner & Buswell 1996). The face in pain is highly salient for observers (Craig et al. 1992; Goodenough et al. 1997; von Baeyer et al. 1984), who ranked eyes the most important cue, followed by brows, eyelids, mouth, head, forehead, and then other body parts (Prkachin et al. 1983). Facial expression has been shown to contribute significantly to observer ratings of adults in pain (Ahles et al. 1990; Hale & Hadjistavropoulos 1997), even when contradicted by a false verbal report of no pain (Poole & Craig 1992). Caregivers of severely cognitively impaired children (van Dongen et al. 1999) and adults (LaChapelle et al. 1999) report that they use facial expression as an indicator of pain, and children too young to use verbal and numerical pain scales are able reliably to use cartoon faces or photographed faces to indicate their own severity of pain, where severity is indicated by eye and mouth shape and depth of nasolabial furrow (Chambers & McGrath 1998). The capacity of humans, from a young age, to interpret the pain face seems adequately established.

As in other facial expression studies, observers of emotional pain faces show some activity in the relevant facial musculature (Dimberg & Ohman 1996; Vaughan & Lanzetta 1980) that appears to indicate empathy via mimicry (Bavelas et al. 1986; Hess et al. 1998), although inattention to the emotional quality of the expression, as when doubting its genuineness, may impair this response (Hess et al. 1998). The emotional concomitants of recognition of facial expression, and mimicry, have not been systematically investigated (McIntosh 1996) on emotion or in pain.

5.6. Extent of voluntary control: Suppression, amplification, simulation

The involuntary nature of facial pain expression is suggested by the data in sections 5.1 to 5.4, its occurrence in infancy, and by findings reviewed below on attempts to suppress it. The questions addressed in research studies are the degree of voluntary control over amplitude – by instructions to suppress or exaggerate pain expression – and the degree to which pain facial expression can be simulated in the absence of pain. Only one study of the latter was found (Galin & Thorn 1993), and its interpretation is complicated by methodological shortcomings. Although often investigated and discussed together, the task of suppression differs in function from that of amplification and of simulation, so these are likely to differ in the evolutionary pressures to which they were subject. Production and detection of voluntarily modified pain expression are reviewed together, because where the interests of the injured individual and the observers conflict, the eventual balance reflects the significance of the payoffs in evolutionary terms. Studies are shown in Table 3.

The extent to which countervailing evolutionary pressures have resulted in the ability successfully to suppress, amplify, or simulate pain expression presents methodological difficulties for the design and interpretation of studies. First, FACS methods do not quantify aspects such as timing, speed, complexity, and asymmetry of expression, which are important in deception (Ekman 1993; Prkachin 1992a) and are likely to affect observer judgments. Second, emotional expressions posed by actors (often for the production of prototype photographs) appear to mix spontaneous and deliberate elements, given some "method acting" component (Hess & Kleck 1990; 1998), and this complicates the use of facial action prototypes to analyse data. Deceptive intent on the part of posing subjects may introduce elements of facial expression related to deception (embarrassment, shame, guilt) rather than to the emotion of interest (Hess & Kleck 1998). This can affect both FACS and judgment studies. Third, Fridlund (1994) has made the telling criticism that these distinctions (in/voluntary, non/emotional, posed or deliberate/spontaneous) may bear no relationship to neural organisation: An evolutionary programme of research would use more naturalistic settings and address evolutionarily stable strategies and cooperation, in addition to those on manipulation and deception that have so far dominated.

5.7. Suppression and detection of suppression

Several studies have used pain patients undergoing clinical examination or executing movements likely to exacerbate pain. In these circumstances, facial expression of pain is de-

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Table 3. *Increases and decreases in frequency and intensity of Facial Action Units in suppressed, amplified and simulated pain by comparison with genuine pain*

<table>
<tr><th></th><th>Pain stimulus/ subjects</th><th>1 inner brow raiser</th><th>2 outer brow raiser</th><th>4 brow lower</th><th>6 cheek raiser</th><th>7 lid tighten</th><th>9 nose wrinkler</th><th>10 upper lip raiser</th><th>12 lip corner puller</th><th>14 dimpler</th><th>20 lip stretch</th><th>23 lip tighten</th><th>24 lip pressor</th><th>25 lips part</th><th>26 jaw drop</th><th>27 mouth stretch</th><th>43 eyes close</th><th>45 blink</th></tr>
<tr><td colspan="2">Pain prototype & variants</td><td></td><td></td><td>**x**</td><td>**x**</td><td>**x**</td><td>**x**</td><td>**x**</td><td>x</td><td></td><td>x</td><td></td><td></td><td>**x**</td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td colspan="19">**Suppression**</td></tr>
<tr><td>Craig et al. 1991</td><td>clin exam/ cLBP</td><td></td><td>f−</td><td>**f**</td><td>**f−**</td><td>**f**</td><td>nm</td><td>**f**</td><td>**f**</td><td></td><td>**f**</td><td></td><td></td><td>**f−**</td><td>**f**</td><td>nm</td><td>**f−**</td><td>**f−**</td></tr>
<tr><td>Hadjist. & Craig 1994</td><td>clin exam/ c + a LBP</td><td>f
i</td><td>f
i</td><td>**f**</td><td colspan="2">**f**
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i</td><td>**f**
i</td></tr>
<tr><td>Galin & Thorn 1993</td><td>cold/ healthy</td><td></td><td>f</td><td></td><td colspan="2">**f**</td><td></td><td></td><td>**f**</td><td colspan="2">**f−**</td><td></td><td></td><td>**f−**</td><td>**f**</td><td></td><td colspan="2">**f**</td></tr>
<tr><td colspan="19">**Amplification**</td></tr>
<tr><td>Craig et al., 1991</td><td>clin exam/ cLBP</td><td></td><td></td><td>**f+**</td><td>**f+**</td><td>**f**</td><td>nm</td><td>**f**</td><td>**f+**</td><td></td><td>**f**</td><td></td><td></td><td>**f**</td><td>**f**</td><td>nm</td><td>**f**</td><td>**f−**</td></tr>
<tr><td>Hadjist. & Craig, 1994</td><td>clin moves/ c + a LBP</td><td>f
i+</td><td>f
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i</td></tr>
<tr><td colspan="19">**Simulation**</td></tr>
<tr><td>Galin & Thorn 1993</td><td>cold / healthy</td><td></td><td></td><td>**f+**</td><td colspan="2">**f+**</td><td></td><td></td><td>**f**</td><td colspan="2">**f**</td><td>f+</td><td></td><td>**f**</td><td>**f**</td><td></td><td colspan="2">**f+**</td></tr>
</table>

f = frequency comparable with genuine pain (**emboldened** where genuine pain shows action unit)
f+/f− = increased/decreased frequency of action unit or action unit combination by comparison with genuine pain
I = intensity comparable with genuine pain (**emboldened** where genuine pain shows action unit)
i+/i− = increased/decreased intensity of action unit or action unit combination by comparison with genuine pain
LBP = low back pain; cLBP = chronic low back pain; c + a LBP = chronic and acute low back pain
nm = not measured

tectable despite the instruction to subjects to try to conceal it (Hadjistavropoulos et al. 1996; Poole & Craig 1992), although overall activity may be subtle and differ only slightly from no pain and unmodified pain expression (Hadjistavropoulos & Craig 1994), or may appear only in specific action units (mouth opening: Hadjistavropoulos & Craig 1994; eye narrowing: Craig et al. 1991; Prkachin & Craig 1995). An extra and uncharacteristic facial action of outer brow raise has also been reported (Craig et al. 1991). These studies are summarised in Table 3. In the only FACS study of healthy volunteers instructed to conceal pain expression (Galin & Thorn 1993), suppressed pain expression shared the frequency of particular FAs both with pain-free and genuine pain expressions (see Table 3), but interpretation must be cautious as the selection of sections for coding may have provided habituated rather than immediate facial expression of pain.

Two judgment studies on observer identification of suppressed pain, using chronic pain patients instructed to suppress pain expression during painful manoeuvres, produced mixed findings. In one, suppressed pain was more often identified as real than as no pain, when these options were provided (Hadjistavropoulos et al. 1996), but judges found the discrimination difficult and rated their confidence in their judgments relatively low. In a second study, observers identified "leakage" of expression around the eyes (Poole & Craig 1992). The studies using induced pain in healthy volunteers differ somewhat: In one study, judges distinguished levels of pain stimulus intensity using facial cues (Patrick et al. 1986); in another (Galin & Thorn 1993), observers appeared to distinguish genuine from manipulated pain expression, although they were not necessarily accurate about whether the manipulation was suppression or amplification. It is probable in this study that some FAUs represented emotion related to deception. In a third study (Lanzetta et al. 1976), levels of pain intensity were apparently not distinguished by observers but a uniformly low pain rating given across levels.

In summary, the FACS data are reasonably consistent on the appearance of pain FAUs when subjects attempt to suppress pain, with reduced frequency of FAUs in the upper and lower parts of the face, and of reduced intensity mainly in the lower part. The data from judgment studies are more mixed, although there are indications that observers detect more than they can confidently report. It may be that in real situations, this is sufficient to instigate a check on the context (and the face) for further information.

5.8. Amplification and detection of amplification

In chronic pain patients subjected to extra painful movement, the instruction to exaggerate led to the use of several FAUs not prototypical in spontaneous pain expression (inner and outer brow raise, lip corner pull, chin raise). Lip stretch and eye closing occurred more frequently than in genuine pain, and blink less frequently, with overall higher frequency and intensity of FAUs characteristic of genuine pain (see Table 3) (Craig et al. 1991; Hadjistavropoulos & Craig 1994; Hadjistavropoulos et al. 1996). There are no published FACS studies of amplification in healthy volunteers subjected to painful stimuli, only of simulation (below).

Although two studies showed detection of amplification from genuine pain at a better than chance level, in a clinical population (Hadjistavropoulos et al. 1996) and in a volunteer population instructed to exaggerate pain (Lanzetta et al. 1976), amplification is not necessarily well discriminated by judges (Poole & Craig 1992). Nor is it clear what judgment heuristics they use: They do not consistently correspond to atypical facial movements identified by the use of the FACS (Hadjistavropoulos et al. 1996). Reference to Table 3 suggests that amplified and simulated expression show most discrepant activity in the upper face, with little change in the lower face. Experimental conditions and instructions may have an important influence: When primed to expect deception (suppression and amplification of pain expression) untrained observers were no better at accurate detection of the actual condition, but gave more conservative judgments across all conditions: suppressed, genuine, and amplified pain expression (Poole & Craig 1992). Observer judgments can also be influenced by priming with information suggesting subject hypersensitivity or analgesia (Prkachin et al. 1983). This suggests not so much detection of simulation but rather modification of judgments based on a good-enough reading of cues.

It is hard to summarise these rather diverse data, and the likelihood is higher in amplification than in suppression of contamination from two sources. Facial movements associated with deception (timing, overlap, and asymmetry) are not identified by FACS methodology but may influence observer judgments. This could explain the discrepancy noted in the study that used both (Hadjistavropoulos et al. 1996). Second, emotions related to deception (shame, guilt, embarrassment) can be described and identified using FACS methodology but are not investigated in any of the pain studies reviewed here that use FACS; again, they are likely to affect observer judgments.

5.9. Simulation and detection of simulation

Simulation of pain in its absence may be a version of amplification rather than a separate function: There are no data with which to address the question at this stage. Although, in general, simulation of emotion produces an impoverished expression (Gosselin et al. 1997), the only study of simulation by pain-free subjects suggested, on FAU analysis, more intense expression than genuine or baseline pain, consisting of more brow lowering, cheekraise, tightening of eyelids, closing eyes, and tightening lips (Galin & Thorn 1993). Although identification was not quantified, feedback on accuracy of judgments appeared to improve it, but it is not clear what cues the judge adopted (Galin & Thorn 1993).

6. Observer judgments

Having reviewed what properties of the facial expression influence observer judgments, we turn to properties of the judge. Relatively little research has addressed the context of the judgment: the relationship of the observer to the person expressing pain, the information and beliefs that the observer consciously or unconsciously brings to the judgment, and the potential costs and benefits for the observer of erring in either direction. Such issues are crucial to an evolutionary analysis (Tooby & Cosmides 1990). In empirical studies, observer accuracy is usually judged by the degree to which the observer's rating matches the subject's rating of pain. In fact, although subjective rating is important if idiosyncratic (Williams et al. 2000), there is no gold standard for pain measurement, nor can pain be represented unidimensionally. Further, this method makes the assumption that the face and the subjective rating express the same dimension/s of pain experience. Exploration of other facial expression, such as sadness, fear, and anger, has not focussed on quantification: It appears to be a peculiarity of pain, related to clinical concerns about judging authenticity.

With a few exceptions there is little variability among observers within a particular group in their accuracy (Hadjistavropoulos et al. 1996). Most judgment studies show "underestimation" of pain in relation to FAUs and the subject's own pain estimate and this is particularly marked where the judges are clinicians (Prkachin 1997). Underestimation of pain by reference to the sufferer's rating is widespread among health professionals and staff who care for elderly people (Forrest et al. 1989; Grossman et al. 1991; Keefe & Dunsmore 1992; Madjar & Higgins 1996; Marzinski 1991), with some contrasting findings of close approximation (Grossman et al. 1991) or slight overestimation of low levels of pain (Zalon 1993). Inadequate analgesia, across ages and illness severity (Bartfield et al. 1997; Demyttenaere et al. 2001; Finley et al. 1996; Marks & Sachar 1973; Marzinski 1991; Schechter 1989; Wilson & Pendleton 1989), constitutes a major clinical problem (Keefe & Dunsmore 1992). A major cancer researcher has even suggested training patients to express pain in ways which doctors and nurses currently recognize (Keefe & Dunsmore 1992).

The common explanation for the phenomenon of underestimation by health professionals is that repeated exposure to pain and professional training develop a relative insensitivity to pain and/or a scale with a higher upper limit. This is used, for example, to explain greater underestimation among more experienced staff (Mason 1981; Prkachin et al. 2001; von Baeyer et al. 1984). Observation of patients with high levels of pain may extend the clinician's reference scale for judging pain intensity; however, the notion that repeated exposure in itself results in lower judgments of pain is contradicted by the findings concerning spouses and caregiving family members as judges. Although accuracy is variable (Madison & Wilkie 1995), overestimation is at least as common as underestimation, even though all studies involved cancer pain (Clipp & George 1992; Dar et al. 1992; Ferrell et al. 1991; Madison & Wilkie 1995). In a study by Prkachin et al. (2001), students with family experience of chronic pain showed a closer approximation to stranger-patients' estimates of their own affective rating of pain than did students with no such experience. This would seem to suggest that exposure to pain improved accuracy, undermining the hypothesis of developed insensitivity. Neither does it support the exposure hypothesis, because in the same study, health professionals estimated patients' pain less accurately than did the students with no family experience of pain (Prkachin et al. 2001). Differences appeared to lie in weighting of what was observed, rather than in sensitivity to variation in facial expression per se: All groups were more accurate at higher levels of pain. The role of feedback (so that the observer can compare his or her estimate with the sufferer's) is unclear: One study found that providing patients' own ratings resulted in more attention to facial expression than when they were unavailable (Poole & Craig 1992), but accuracy was not estimated; another found that training had relatively little effect (Solomon et al. 1997).

In normal infants and children, nonspecific signs such as respiration, activity, and vocal cues are used as well as facial behaviour by nurses (Craig et al. 1996; Goodenough et al. 1997; Hamers et al. 1996; Howard & Thurber 1998; Hudson-Barr et al. 1998; Pigeon et al. 1989; Vetter & Heiner 1996). The caregivers of nonverbal cognitively impaired children and young adults attended most to vocalisation; facial changes of some sort were noted by 80%, with changes in the eyes the most frequent at 50% (McGrath et al. 1998), but it is possible that there was a lower frequency of face to face interaction than between verbal children and their parents or caregivers. Underestimation of pain in infants and children occurs both in health professionals (Hudson-Barr et al. 1998; Selbst & Clark 1990; Vetter & Heiner 1996) and less consistently in parents (Chambers & McGrath 1998; Chambers et al. 1998; Craig et al. 1996): both nurses' and parents' pain ratings may be unrelated to those of the children rated, through overestimation and underestimation (Demyttenaere et al. 2001). Actual detection of pain from facial expression in photographs of neonates undergoing painful and nonpainful stimuli was poorer in health professionals than in a control group who were not health professionals (Balda et al. 2000), the association remaining even when the number of children in health professionals' families was controlled. An elegant study using child patients' own ratings of current pain and threshold at which they desired analgesic indicated serious undermedication in the first few days following major surgery, a very common clinical event (Demyttenaere et al. 2001). Although inadequate analgesia is likely to arise from underestimation of pain, a study by Hamers et al. (1996) found that more experienced nurses were less willing than less experienced nurses to give analgesics to children, although their estimates of pain did not differ. Exposure through professional experience is a possible explanation for these findings, but it cannot account for the inconsistent estimations by parents.

If experience and training do not improve accuracy, but instead professionals with responsibility for providing comfort develop increasing conservatism in pain estimates with exposure to strangers in pain, what biases are affecting judgment? There is some experimental work that casts light on this, albeit not necessarily using facial expression.

Contextual variables can affect judgments of pain and the decisions that arise from them. In studies using written vignettes, both students and experienced physicians who estimated pain in cases with differing medical evidence showed an interaction between the pain level provided in the vignette and the existence of medical evidence, with discounting of high pain levels where medical findings were absent (Chibnall & Tait 1995; Chibnall et al. 1997; Tait & Chibnall 1997). Although an invalid inference, expected severity of pain from an identifiable injury may influence observer judgment of pain in adult patients (Hadjistavropoulos & Craig 1994; Todd et al. 1994; Wilson & Pendleton 1989), and consistent with this, the two studies that showed reasonable approximation of clinician to patient estimate involved an authenticated basis for pain, postoperative (Zalon 1993) or cancer (Grossman et al. 1991). Some biases are less contextual than characteristic of the observer. Observer beliefs concerning employment and risks of opioid addiction may also affect judgments of pain and analgesic requirement by physicians (Carey et al. 1988; Marks & Sachar 1973), who also rate less pain for more physically attractive pain patients (to whom better health is consistently attributed) than for less physically attractive pain patients on videotape (Hadjistavropoulos et al. 1995). By contrast, spouses who believed that their spouse-patients with cancer minimised their pain, tended to overestimate pain severity.

In children, contextual variables are also used: Parents and nurses rated pain on venipuncture in sick children lower for children who were more experienced with venipuncture and higher where venous access was difficult (that is, more damage was inflicted), although neither was represented in the young patients' own pain ratings (Manne et al. 1992). The same study showed parents' pain ratings to be significantly predicted by their own anxiety and expectations of painfulness taken before the venipuncture, but a similar examination of parents' ratings on immunization of healthy children found that parents' anxiety had no influence on pain ratings (Breau et al. 2001).

These findings suggest that observers use context and beliefs or judgment biases to modify information from the facial (and other) expression of pain. Where facial expression goes unnoticed or uninterpreted and patients cannot express pain verbally, even unambiguous medical information may not lead to the suspicion of pain. For example, Marzinski (1991) found that only one quarter of the residents of an Alzheimer's unit with typically painful conditions, including metastatic cancer, routinely received analgesia, but Sengstaken and King (1993) found that chronic pain problems went unrecorded and unmedicated by the attending physician in more than one third of communicative residents of an intermediate care geriatric nursing home, and given that few noncommunicative residents were identified as suffering from chronic pain, the authors estimated a high level of underdetection. Experimental studies represent ideal conditions for judgment of facial expression: Judges attend under instruction to selected videotapes of subjects. In clinical settings, detection also depends on the frequency of spontaneous expression, which in cancer patients moving in ways that exacerbated their pain approximated one expression every two minutes detectable on videotape (Wilkie 1995). The clinician divides his or her attention between the patient's face, body, notes, and other sources of information, and may miss brief facial expressions. Clinicians may judge chronic pain patients at rest by reference to an expected acute pain face and therefore discount the patient's report of pain; they may also observe an expression that blends pain with fear, embarrassment, anger, disgust, and sadness: Confusion of one emotional expression with another can be investigated (e.g., Kappesser & Williams 2001; Keltner & Buswell 1996; Stenberg et al. 1998). In addition, observers' attention to the question of veracity may suppress an affective or empathic response (Hess et al. 1998), degrading the quality of judgment made, a condition also accessible to empirical investigation.

The information here is consistent with the evolutionary model elaborated in section 3. The observer who is a potential helper must be alert to the possibilities of social cheating, and give help (benefit) only to those who pay the cost, that is, who genuinely have pain. So they look for confirmation, such as evidence of injury or clinical signs of structural damage or pathology. However, where these are weak or absent, and where benefits are believed to be of considerable value to the person complaining of pain (such as sanctioned and paid absence from work, entitlement to welfare support proportional to severity of disability, or access to abusable drugs), suspicion is heightened and the judgment of pain modified. Even in the experimental setting, priming of observers by warning that they will see no pain, suppressed, genuine, and faked pain expressions in chronic pain sufferers undergoing an acute exacerbation with movement results in underestimation of pain across conditions (Poole & Craig 1992). The experimental subject judging a stranger has nothing to lose by overestimating pain; the parent, spouse, or family member may need to protect against repeated exploitation or may be concerned to provide fully for the patient's needs, and the data above offer fewest clues to the influences on their judgments. Health professionals are gatekeepers for many benefits, and risk losing face among their peers if they appear gullible to patients' complaints, and may be subject to professional or legal investigation if they prescribe opioids much more generously than their peers. Although the operant model of pain cannot be held responsible for the requirement that health professionals and others must make credibility judgments, literature arising from it has contributed to the attribution of agency to a variety of contingent benefits in the complaint of pain. This is further developed in the next section.

7. Evolved propensities

In integrating the hypotheses and data presented, it is important to keep in mind that "Evolution does not create specific behaviours; it creates mental organisations and inference systems that make people behave in particular ways. The inference systems are activated whenever information in a certain format from the environment is presented" (Boyer 2001, p. 268). This article has attempted to examine what information presented by the environment activates or deactivates a hypothesised inferential system or evolved propensity. My aim is to make as explicit as possible the biases that operate in the production and judgment of facial expression of pain. It should be noted that neither operant nor evolutionary explanations should be taken to imply conscious intent in the modulation of pain expression or the judgments made by observers acting in accordance with evolved propensities (Daly & Wilson 1991), although cooperation with certain experimental conditions requires conscious intent in the signaller, and judgment of conscious intent is required to diagnose malingering.

To what extent does the evidence support contextual evolved propensities or inference rules for the production, detection, and interpretation of facial expression of pain? For the strategic expression of pain in the presence of caregivers, there are suggestive findings on which it would be unwise to rely heavily: Both Kleck et al. (1976) and Badali (2000) showed that pain expression was greater when subjects were alone than when they were observed or they believed themselves observed by neutral onlookers. This suggests an important thought experiment or prediction: that the increase in pain behaviour observed in the presence of solicitous others (Block et al. 1980; Flor et al. 1995) and health care staff could be the release of suppression of pain expression, rather than its amplification. A parallel could be found in the expression of grief, where temporary loss of an attachment figure in infancy and young childhood produces a consistent pattern of emotional responses including expression of grief and anger to the attachment figure when that figure reappears, but not reliably to other adults available in the interim (Weiss 1991). In adulthood, grief is expressed among kin and friends rather than among strangers or alone (Parkes 1972), although with some cultural variation; and recent research on shared and nonshared negative emotional experiences confirms the tendency for individuals to mask and conceal emotion that they choose not to share (Finkenauer & Rimé 1998). More systematic work in the facial expression area concerns smiling, which was better predicted by the interactive nature of the social situation than by happiness ratings across social and nonsocial situations (Fernandez-Dols & Ruiz-Belda 1997), and the apparently inhibitory effect of strangers on facial expression of emotional reactions to pleasant and unpleasant images (Buck et al. 1992). Better understanding of pain facial expression may offer insights beyond pain: A broader appreciation of facial expression would encompass need states as well as emotion.

Findings of greater facial expression of pain in the presence of potential caregivers than in their absence are compatible both with the evolutionary hypothesis that the presence of potential caregivers prompts the release of suppression of pain facial expression, and with the operant hypothesis that pain expression is amplified on the basis that amplification has been rewarded in the past. Nevertheless, distinguishing between the two is of considerable clinical importance. Until it is established, proponents of the operant model in pain would do well to express caution about the unscientific use of the model in the imputation of secondary gain when patients show more pain behaviour in clinical interview, than when they believe themselves unobserved: Ambiguity over whether such communication is intentional allows the assumption that behaviours are deliberately produced, or not suppressed; an assumption that is to the serious disadvantage of the patient and contributes to the judgment of malingering.

A propensity characterised as "Don't hide pain in the presence of a potential caregiver," would encourage free expression of pain in the presence of solicitous others and of those whose professional duty it is to attend and minister to pain, as well as under experimental demand. In the presence of others not expected to provide support of any sort, or when alone, facial expression of pain would tend to be suppressed. There is some support for this in the finding that, for children, although the presence of parents may disinhibit some pain expression, the pain experience is rated as less when parents are present than when they are absent but expression is reduced (Stoddard 1982 cited in Craig et al. 1996). Evolutionary pressures, however, will have acted on expressiveness in general, not only of pain, so that the demands of pain expression and detection will not be its only determinants.

What of the observer? Fridlund's (1994) framework of the requirements for the observer to show sensitivity to displays, selectivity about particular components of the display, and skepticism about its meaning, may provide a heuristic for further investigation. There appears to be some capacity to detect pain despite attempts at suppression, and observer estimates of pain at low levels can approach or, rarely, exceed the sufferer's estimate. However, observers may also tend to discount pain, more at higher pain levels, when there is not supportive evidence of injury, and when primed to expect deception. Professionals making judgments of pain tend to have more confidence in their judgment than is warranted (Goodenough et al. 1997; Lander 1990). On the basis of FAU findings, suppressed pain appears more likely to be identified by observers as pain present, than simulated pain is identified as pain absent (Hadjistavropoulos et al. 1996) – consistent with the costs and benefits in evolutionary terms. An anticheating device

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to protect the potential help-giver might take the form of specific detection of amplified or simulated pain, for which the experimental evidence is equivocal at best; or it might take the form of a general conservatism about estimating others' pain, which is influenced both by contextual information and by personal beliefs.

As described earlier, the cost to health professionals of overestimating pain (and overprescribing treatment) is considerably higher, and therefore more warranting conservatism, than for neutral onlookers. Tellingly, when health professionals predict the extent of pain to be expected from medical procedures they do not necessarily underestimate it (Hodgkins et al. 1985): It is their reading of facial expression that results in underestimation. Although sensitivity training (Solomon et al. 1997) may offer some possibility of improving accuracy, recognition and correction of systematic bias might offer more. For other caregivers, it should not be assumed that the needs of, for example, children and their parents necessarily complement one another: Parents and caregivers may tend toward conservatism to avoid exploitation. The evidence does support the generalisation that observers whose power to dispense benefits, such as health professionals and parents but not spouses or strangers, is far greater than that of the patient to obtain them by other means are more likely to underestimate pain and/or to underprovide related benefits such as analgesics. In the Dar et al. (1992) study, spouses who overestimated patients' cancer pain were also more liberal about use of opioids.

8. Synthesis and possibilities

This target article constitutes an exploration and elaboration of ideas about pain and behaviour associated with pain in an evolutionary perspective, using available findings on facial expression of pain (albeit none arising directly from the framework of evolutionary psychology). Applying the criteria (described in sect. 3) for appraising the hypothesis that a specific behaviour or set of behaviours is the expression of an evolved propensity (Tooby & Cosmides 1990; 1992), there is good evidence that pain facial expression is specific and that it is distinguished from other facial expressions by onlookers. The balance of costs and benefits for the person in pain and the onlooker have been described for the acute threat phase and in the later recovery phase, as have their implications for survival, such that their advantage under natural selection requires no additional argument. Finally, a hypothesis has been proposed concerning the cognitive inferences that would govern the behaviour. The model draws on established work on mechanisms of altruism and help-giving and, in that context, on the specific sensitivity to social cheating.

Many important questions remain. Some concern the content of the facial expression of pain: distinctions between acute and chronic pain states, and the extent to which context affects the encoding of different components. Pain varies in quantity, quality, temporal properties, and affective tone, whereas experimental work mainly addresses only pain intensity. These different dimensions are also differently represented in self-report, making convergence an empirical question rather than an expectation. Further questions concern other pain behaviours, such as limping, guarding, or rubbing, which, although clearly more accessible than facial expression to voluntary control, should not unquestioningly be assumed to be intentional and manipulative. Then there is the relationship between facial expression and other pain behaviours, because they generally occur together: It has been suggested that other motor behaviours add emphasis (Argyle 1988), even to the extent of a full display (writhing, thrashing) demonstrating "no cheating, no faking," given the high costs of activity to an already stressed organism (Bateson 1991). The emotional content of facial and other pain expression is important, and issues of differentiation from, and overlap and blending with, other emotional expressions require investigation (Fridlund & Duchaine 1996; Prkachin 1997). The distinction made by many clinicians in assigning all emotional expression and behaviour to a "psychological problem" category degrades assessment – when it is intended to refine it.

Considerable methodological problems explain, in part, the lack of evidence on these questions. Ideally, dynamic recording and encoding methods could provide information on sequence, timing, and duration of expression; spontaneous and deliberate expressions differ (Hess & Kleck 1990) in ways that are lost in photographs. A more serious problem is that in laboratory studies of volunteer subjects, the pain has little meaning and high predictability and controllability, thus little emotional content or threat value. Additionally, in research on observer responses, posed and spontaneous expressions frequently differ in symmetry, timing, and content (Argyle 1988; Borod et al. 1997; Hess & Kleck 1990; Scherer 1992), and the instruction to pose may produce some signs of deception (such as blinking) that interfere with the posed expression and observers' judgments (Hess & Kleck 1990).

Empirical and observational studies are needed both on the production of facial expression and on its detection and interpretation, and a major purpose of this paper is to stimulate empirical work as well as theoretical debate. On pain facial expression, evidence is thin on universality (where formulating unconfirmable hypotheses presents substantial difficulties, and the study of cultural differences in pain expression lacks an adequate model of evolved and learned behaviours); on primate expression of pain and its social context; on everyday painful events in humans and onlookers' responses to them, preferably covertly observed; on variation in pain facial expression over time and across settings. More ecologically relevant refinement of current methodologies (Carroll & Russell 1996) could include chronic pain patients undergoing examination that exacerbates pain in a clinical setting where the results of the examination have important implications for the patient; and the manipulation of expected cues for suppression or expression of pain, such as the presence of strangers, sympathetic others, or potential professional caregivers. Observed behaviour, rather than self-report, constitutes the datum of interest, and avoids falling into unintended assumptions of consciousness and intentionality, which are not the currency of evolved propensities for behaviour (Daly & Wilson 1991).

Variability in observers' judgments has been described in relation to their beliefs and how these affect their attention, their interpretation, and weighting of various aspects of signals (Prkachin & Craig 1995). Systematic investigation of the contingencies affecting their judgments and responses could test predictions drawn from an evolutionary perspective of costs and benefits to those observers. There may be specific pain-related propensities, as exist for other cognitive processing of crucial information (Prkachin & Craig 1995), such as the apparently enhanced memory for the faces of cheaters (Mealey et al. 1996), and priority processing of angry faces (Hansen & Hansen 1988).

The study of malingering at present consists of a critical evidence-based approach (e.g., Chibnall & Tait 1995; Main & Spanswick 1995; Mendelson 1992) and misguided attempts to devise malingering detection tools (reviewed by Fishbain et al. 1998). Despite consistent evidence of a low base rate (Chibnall & Tait 1995; Mendelson 1992), an antitherapeutic preoccupation with malingering and exaggeration persists in the pain literature and clinical and medicolegal practice. Understanding of the phenomenon, and of the preoccupation with it, could be advanced by testing the hypotheses developed above, using methodologies of manipulation of contextual information and material relevant to biases, and adopting methods from studies on cooperation, help-giving, social cheating (Cosmides & Tooby 1992), and deception (Ekman & O'Sullivan 1991). It is also important to address the largely neglected problems of concealment of pain and observers' failure to recognise it or estimate its magnitude. The assessment and management of pain in infants and young children, and in cognitively impaired people of all ages, has only recently attracted interest, and proxy judgments by caregiving adults is still the norm in clinical practice. Facial expression offers the best means for accurate assessment in nonverbal subjects, and an important source of information in verbal ones.

This article aims to encourage the development of evolutionary perspectives and the generation of relevant data. Of particular concern is the clinical arena in which I believe an evolutionary approach helpfully challenges the dominant operant approach whose over-application has led to the assumption of benefits and disregard of costs to the person in pain who finds him or herself suspected of factitious complaint, and undertreated. The type of cost-benefit analysis generated by an evolutionary approach applied to the behaviour of the person in pain, and of the person who observes him or her, will bring better understanding of how conditioning processes affect or do not affect unconditioned behaviours associated with pain. An evolutionary perspective offers much to the pain field, beyond application to facial expression and pain behaviours: A focus on the functions of pain, and an integrated rather than separate approach to its various components, can only further understanding of pain.

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NOTES

1. These propensities are functionally specialised cognitive adaptations that guide thinking and behaviour in that domain of function, and therefore constitute the proper unit for describing and explaining adaptation. Like many cognitive processes, there is no implication of conscious intention (Daly & Wilson 1991). An example that makes the distinction very clear is given by Cronin (1991): The moth's flying into a candle flame is maladaptive behaviour, but the moth has evolved (long before candles appeared) to fly in a straight line by using effectively parallel rays from the moon, whereas light rays from a nearby source converge on the flame, as does the moth. Widely accepted examples in humans of functionally specialised cognitive adaptations include language learning and face perception. Although adaptive in the environment in which they evolved, such propensities can have significant costs in the current environment, as they do for the moth.

2. The Facial Action Coding System (FACS) describes 44 discrete facial actions (of a single muscle or a combination) that can be distinguished by observers and, in particular combinations, constitute prototypical facial expressions (see Table 1). They are analysed using trained raters who view sections of videotaped facial expression and record the occurrence, frequency, and/or intensity (on a five point scale) for those movements for which it is appropriate, for example, intensity for brow lower but not blink. The main advantages of using FACS are that it is theoretically neutral and does not presume any emotion categories (Grunau & Craig 1987); it is well operationalised; and trained raters generally achieve high reliabilities. It has the disadvantages that it neglects duration of pain expression (LeResche & Dworkin 1988); it cannot represent temporal sequences, timing, or asymmetry, dimensions of facial movement that are particularly relevant in deliberately manipulated expression; and analysis is time-consuming so that use outside research settings is rare.

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What role does intersubjectivity play in the facial expression of pain?

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Abstract: The facial expression of pain is the end product of a complex process that is, in part, emotional. The evolutionary study of facial expression must account for the social nature of human consciousness and should address the questions of why empathy exists, the adaptive importance of empathy, and whether facial expression is a mechanism of empathy and second-person consciousness.

Research over the past decade has made it increasingly clear that human pain is a complex process that emerges, not from the arrival of a sensory message at the somatosensory cortex, but rather from massive, parallel, distributed processing in multiple areas of the brain. These areas otherwise contribute to the production of emotion, cognition, and somatosensory awareness. "Bottom-up" evidence derived from neurophysiology, based on line-labeling approaches, indicates that nociceptive signals activate the thalamus, the locus coeruleus, the hypothalamus and other structures (Price 2000; Willis & Westlund 1997). The locus sends extensive noradrenergic projections throughout the limbic brain to areas involved in the production of negative feeling states, to the hypo-

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thalamus, which controls sympathetic nervous system arousal and the neuroendocrine stress response, and to the cerebellum, which controls motor movements and facial expression (Amaral & Sinnamon 1977; Bremner et al. 1996; Charney & Deutch 1996; Redmond & Huang 1979; Svensson 1987). "Top down" evidence from functional brain imaging studies supports bottom-up neurophysiology. More than 130 studies show that people in pain, whether of pathological or experimental origin, demonstrate metabolic activity in limbic and motor brain areas, as well as somatosensory cortex (Bromm 2001; Davis 2000; Peyron et al. 2000; Rainville 2002). The facial expression of pain, therefore, is the end-product of a complex, dynamic process that is, in part, emotional. Why pain should have a facial expression, is an intriguing question.

Williams has provided a valuable and provocative review of this field and related issues. She is right to direct attention to evolutionary origins. It would be naive to study the facial expression of pain as purely a mechanical reflex response to central processing of tissue trauma. It might also be naive to view it purely as an instrumental behavior intended to elicit responses from others. Characterizing it as simply an outward expression of an inner emotional state also risks oversimplification. The facial expression of pain is probably all of these things and more, and its evolutionary purpose is entangled with the broader mysteries of why consciousness itself evolved, and why human consciousness depends so heavily on social relationship.

The field as a whole tends to address the facial expression of pain, and the larger phenomenon of the facial expression of emotion, in a stimulus–response framework. Facial expression is a stimulus that one person produces to which another person responds. This assumption is implicitly evident in Williams' discussion of the area and the issues. We suggest that this framework constrains discussion of the evolutionary origins and nature of human facial expression. Facial expression recognition invariably involves an interpersonal interaction between the person who generates the expression and the person who recognizes that expression. If this is so, then social interaction should be a central focus in studying the human facial expression of pain.

Work in the field of consciousness studies helps extend thinking about the evolutionary origins and socially adaptive functions of facial expression. Freeman (1995) emphasizes the fundamental point that the human brain evolved not to exist alone, but rather to relate to other brains. Therefore, human consciousness has a fundamental affiliative quality. Donald (1993) notes that the process of evolution demonstrates a steady refinement of social experience and its display. Social communication appears to be important for the development of higher social intelligence. In Adolphs' (2002) view, social communication and emotional response go together, typically involving posture and vocalization, as well as facial expression. Thompson (2001) asserts that human consciousness is formed in the dynamic interrelation of the self and the other, and therefore it is inherently intersubjective in nature. A concrete encounter between the self and another, Thompson holds, fundamentally involves empathy. We suggest that the facial expression of emotion, and of pain (which is in part emotion), is one of the major mechanisms of empathy.

Wild et al. (2001) point out that viewing facial expression of emotion triggers an emotional response in the perceiver that mirrors the emotion in the person who originally displays the emotional expression. This appears to hold in the case of pain, which is partly emotion. We do not feel the sensory aspects of another's pain, but we may resonate with the agony of a person in pain when we encounter facial expression. The degree to which we "share" another's agony depends on empathy.

There are three positions from which we may address human consciousness, and empathy is central to the second-person position. The first position, or first-person, is the individual's personal reality; only he or she can experience this directly. Describing a person's experience from the outside (behavioral observation, coding of facial action) is the third-person position. The second-person position is shared awareness grounded in empathy. Although we all recognize that this occurs, and indeed engage in it, very little research exists on second-person consciousness. The evolutionary study of facial expression, we propose, must approach the question of why empathy exists, why empathy is sociobiologically important, and the extent to which facial expression is a mechanism of empathy and second-person consciousness. Applied to the facial expression of pain, these issues point to the evolutionary origin of compassion.

Cole (1998; 2000) views the face as an essential organ for engaging in empathy and for sustaining human relationship. The face is an interlocutor between the self and the world, and it is central in the sense of self. In human interactions, the face provides a dynamic, embodied representation of emotion, sharing feelings and moods from moment to moment. Human interactions are, in part, facial conversations, usually mutually reinforcing. Through facial conversation, an individual can enter into the subjective experience of another, sharing feelings and moods. We submit that an evolutionary approach with a focus on the role of embodied expressions, such as facial expression, will facilitate the study of pain and the assessment of clinical pain.

Pain in the social animal

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Abstract: Human pain experience and expression evolved to serve a range of social functions, including warning others, eliciting care, and influencing interpersonal relationships, as well as to protect from physical danger. Study of the relatively specific, involuntary, and salient facial display of pain permits examination of these roles, extending our appreciation of pain beyond the prevalent narrow focus on somatosensory mechanisms.

An integration of evolutionary theory and empirical findings on the facial expression of pain provides an excellent opportunity to explore interpersonal parameters of pain. Williams' paper compels one to reflect on both continuities across species and unique features of pain emerging in the course of evolution that would distinguish between human and nonhuman species. Progressive emergence of *Homo sapiens* dates back more than half a million years, with clear evidence for biologically and behaviorally modern humans traceable to at least 40,000 to 50,000 years ago. Language, communal living, and other complex social interactions signify changes in brain organization. These transformations from nonhominid progenitors and ancestors of *Homo sapiens* in adaptive flexibility and competence would have been accompanied by added complexities in the nature of pain in the lives of present-day humans, relative to those of progenitor and other species.

Attempts to summarize the functions of pain usually have a narrow focus upon its protective role as a warning of danger from tissue damage, thereby motivating escape from threats to survival and recuperative efforts. This spotlight upon personal functions is complemented by characterizations of pain as an inherently private subjective experience, incomprehensible to observers other than through inference when observable manifestations (verbal, nonverbal, or physiological) are available. But this focus on intrapersonal features neglects what now appear to be inevitable public features that also effectively serve important interpersonal functions. Displays of pain signal danger to usually instigate sympathy and care-giving, and influence the relationship between the person in pain and others. Ancestral humans were vulnerable to efficient predators and led lives closer to immediate environmental dangers than our contemporaries. Behavioral evidence of pain in humans (and many animal species) signals threat to the community, as group survival must have depended upon the collective contributions and well-being of its members. But pain would seem to go further to facilitate and enhance feelings of interpersonal connection. For example, the vulnerability of infants to pain evokes strong feelings of concern, tenderness, and nurturance in adults, particularly kin, with the emotional sensitivity and caring of others affecting bonding, attachment, and feelings of security (Craig 2002). Many other beliefs, sentiments, and values, verging on the domains of morality and ethics, could be cited to emphasize fundamental interpersonal dimensions of pain.

These complex social and psychological reactions require expression of pain that is recognized as such by others. Nonverbal expression serves to communicate painful discomfort very effectively. Nonlinguistic vocalizations can warn others or enlist help from a distance, but facial expression of pain provides more specific information. Facial displays evoked by rapid onset of pain, whether fresh or an exacerbation of persisting pain, tend to be automatic, relatively fixed, and lacking voluntary control. Williams' summary makes it clear that the reaction probably cannot be wholly suppressed. These features of the display of pain effectively demonstrate continuity across species in the capacity to experience and display pain, but the interpersonal significance is particularly enhanced in social animals. Therefore, pain appears to serve multiple purposes for humans, with the social functions very substantial.

The purposes of pain behaviors would have evolved over time. It has long been appreciated that actions serving nonsocial functions can be co-opted and exaggerated for their communicative value (Darwin 1872; 1965; Fridlund 1991; Tinbergen 1952). Unlike limb and bodily movements, the facial display during pain can only minimally protect during injury, for example, narrowing or closing the eyes to protect them. Facial grimaces cannot eliminate or terminate the source of pain other than through eliciting the interventions of others and do not appear to serve homeostatic functions. Usefulness of the facial display of pain, as summarized by Williams, is wide-ranging (Craig et al. 2001). It is evident at birth, even in preterm neonates, and persists in healthy children and adults, and even in the presence of intellectual disabilities, pervasive developmental disorders, cognitive impairment, and senile dementia (Hadjistavropoulos et al. 2001). This availability of the facial display of pain confers adaptive benefit on the individual, kin, and others, but only when attended to by observers. When available, language complements nonverbal displays, but it requires high levels of cognitive competence and experience, and appears to fulfill different functions (Hadjistavropoulos & Craig 2002).

Pain behavior is sensitive to social contexts, despite the relatively automatic nature of facial expression. Sweet et al. (1999) observed sensitivity to social contingencies in infants. While the operant approach had merit in directing attention to the formative impact of the social consequences of pain, Williams makes it clear that the account is by no means comprehensive, and it contributes to destructive imputations of conscious intent. Pain expression has the powerful impact of instigating efforts of others to relieve suffering and to facilitate healing. Because these are limited resources and humans are capable of deceit and selfishness (Hill & Craig 2002), it seems reasonable to socialize pain expression such that it is used conservatively and to encourage personal self-management (Chambers et al. 2002). Kleck et al. (1976) and Badali (2000) provide evidence confirming Williams' proposition that pain expressions would be suppressed when the person in pain was in the presence of others who would not be expected to provide support.

Williams' paper lays out a fascinating research agenda further exploring manifest evidence of pain as a form of social communication, the role of facial expression as a measure of pain experience, and other interpersonal aspects of pain. Beginning with Melzack and Wall (1965) and continuing with prominent investigators today (Bromm 1989; Mao 2002; Willis 1995), there has been criticism of the nearly exclusive focus on pain as sensory experience. Of course, this reflects the methodological convenience of studying pain in nonhuman mammals. Exploration of social parameters can redress some of this neglect of uniquely human features of pain.

To express or suppress may be function of others' distress

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Abstract: We argue that pain behaviour cannot be wholly accounted for within the operant model of Fordyce (1976). Many pain behaviours, including facial expression, are not socially reinforced but are evolutionarily predetermined. We urge researchers to take into consideration other learning accounts. Building on the idea that pain sufferers learn to suppress the expression of pain, we begin the development of a framework for a relational understanding of pain complaint.

Williams is to be applauded for her endeavours in reanalysing pain behaviour, particularly the facial display of pain sufferers, from an evolutionary perspective. In this account she poses previously unanswered questions and provides thought-provoking hypotheses and potential avenues for empirical investigation. We will limit our contribution in this debate to two emergent issues: the status of the operant conditioning model of chronic pain, and the role of observers in the context of pain behaviour.

Williams is correct to criticise the empirical status and theoretical underpinnings of the operant conditioning model of Fordyce (1976). Indeed, with the exception of some discrete reflexive and autonomic responses, the idea that all pain behaviour is learned by trial and error, occurring whenever the benefits outweigh the costs, is now simply incorrect. First, several common features of pain behaviours are hard-wired. Their specific complex form is finely tuned to the environment (Bolles & Fanselow 1980; Konorski 1967; Watkins & Maier 2000), but the common route is not open to adaptation. For these reasons we have repeatedly attempted to redefine the essential and primary quality of pain as a threatening urge to escape that interrupts behaviour and demands attention (Eccleston & Crombez 1999). Second, although it is obvious that learning about painful experiences has survival value, not all pain behaviour results from operant reinforcement schedules. Many pain behaviours can result from learning best described by mechanisms of classical conditioning.

In the study of pain, researchers began neglecting modern classical conditioning when the operant behavioural model began to dominate the field (Crombez et al. 2002; Goubert et al. 2002). Classical conditioning is not restricted to the learning of "spit and twitches." Complex forms of behaviour can also be classically conditioned (see Brown & Jenkins 1968; Hollis 1982), including some forms of avoidance behaviour (Bolles 1972). It is of importance that these forms of learned behaviours are less sensitive to operant reinforcement schedules. They may persist despite devastating and negative consequences (Mackintosh 1983). Third, the malleability of pain behaviour, as suggested by Fordyce's operant model, is probably restricted. Modern learning accounts have demonstrated that operant behaviour does not emerge within a vacuum, but is often rooted within old phylogenetic motivational systems (see Blanchard & Blanchard 1988; Bolles 1970; Garcia & Koelling 1966).

The basic axiom of Williams' evolutionary account, that the facial display of pain is hard-wired, is of utmost importance. It implies that pain displays are not shaped by social reinforcement, but that people learn to (partially) suppress and control the facial display of pain in particular situations. This is a careful, subtle but crucial repositioning. Her account matches far better with clinical experience and empirical evidence, and has also constructive implications for social interaction with pain sufferers. Indeed, the operant conditioning model of pain has led to persistent and popular misunderstandings (Eccleston et al. 1997), particularly the pernicious and erroneous idea that pain behaviour is a deliberate strategy that occurs whenever the benefits outweigh the costs. Pain behaviour, including facial display, is contingent upon a more complex set of interactive influences, rather than a conscious decision to exaggerate behaviour. We are only now beginning to understand the extent and rigidity of biases in observer judgements of pain, commonly considered as inaccuracies in judgement (Chambers et al. 1998).

Williams suggests that parents and caregivers may tend toward conservatism [of judgement] to avoid exploitation. We suggest taking this hypothesis a step further. Parents and caregivers are often characterised as powerful and capable of providing care. However, two features of everyday analgesic behaviour are frequently overlooked. First, in comparison with the number of expressions of pain and explicit or implicit requests for analgesia that occur on a daily basis (e.g., Fearon et al. 1996), the number of successful caregiver analgesic behaviours must be spectacularly low. Analgesia, with the possible exception of anaesthesia, is difficult to achieve and when successful is slow in most cases. In short, most pain complaints are delivered and received by observers incapable of delivering the desired response. Second, it should be remembered that when successful analgesia is achieved, its effects are commonly distal to the pain behaviour. It is difficult to imagine exactly how this type of pain relief is a reinforcer of pain behaviour. Instead, we suggest that an evolutionary perspective of the facial display of pain as a signal of trouble and as a request for help only makes sense in the context of the immediate effects it elicits in the potential caregiver.

In line with this idea is the finding that viewing persons in pain affects observers primarily by eliciting distress (Batson et al. 1987; Vaughn & Lanzetta 1981). Similar findings have been found in studies of primates in which monkeys become distressed by observing other monkeys in distress (Mineka & Cook 1993). It is possible that the mismatch between observer and patient on a judgement of pain is at least partially a function of the observer's distress and the failure to help. Underestimation in the context of chronic or procedural pain could be viewed simply as a defence, or as a method of reducing distress in the caregiver. Similarly, attempts to suppress pain expression can be understood as a function of the relationship between patient and caregiver. The desire to limit distress in others may be more adaptive than the expression of pain. It is therefore no surprise that 72% of patients suffering from chronic pain find talking about their health-related emotions to others unhelpful (Herbette 2002). This percentage is in sharp contrast with the general belief in nonclinical samples that the disclosure of emotions is beneficial (Rimé et al., 1998). Taking further the idea that facial expression of pain in the presence of potential caregivers is a release of the suppression of pain expression, we therefore hypothesise that such a release may be not only a function of the perception that potential caregivers are agents of analgesia, but also a function of the perception that they will be robust in response to the display of suffering, and will not avoid, flee, or attack.

We are grateful to Williams for provoking debate into the neglected field of the communication of pain and distress. Analgesic behaviour, or its absence, is a rare topic of investigation. If we are to understand the expression of pain and the complaint of suffering, we must study it within its relational context.

Psychophysical studies of expressions of pain

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Abstract: What differentiates expressions of pain from other facial expressions? Which facial features convey the most information in an expression of pain? To answer such questions we can explore the expertise of human observers using psychophysical experiments. Techniques such as change detection and visual search can advance our understanding of facial expressions of pain and of evolved mechanisms for detecting these expressions.

In the last section of her target article, Williams notes that "Empirical and observational studies are needed both on the production of facial expression and on its detection and interpretation, and a major purpose of this paper is to stimulate empirical work as well as theoretical debate" (sect. 8). This is the focus of our commentary. We discuss the visual detection and interpretation of facial expression, and the existing empirical evidence for evolved propensities based on recent psychophysical studies such as visual search, eye movements, and change blindness. We discuss implications of these studies and suggest new directions for research that will constrain future theoretical accounts of evolved capacities for the detection and interpretation of pain.

Several studies suggest that negative expressions receive more attention than positive. Studies of attention, for example, reveal that faces displaying negative emotions interfere more with cognitive tasks than faces displaying positive emotions (White 1996). Moreover, in visual search tasks, observers detect negative facial expressions more quickly than positive (Eastwood 2001). Future experiments using a "flanker" task can investigate the interference associated specifically with expressions of pain, and from this infer the degree to which this expression attracts visual attention. In this task observers make judgments about a central face (e.g., about its gender) while ignoring two flanker faces, one on either side of the central face. The two flanker faces differ from the central face, but are identical to each other in identity and expression. By changing the expression of the flankers from trial to trial we can measure, via reaction times and error rates, how much interference each expression generates and therefore how much attention each expression attracts. Pain may attract more attention than other negative expressions such as anger. On an evolutionary level, pain can carry mixed messages: a warning of danger or a cry for help. Since our response to an individual expressing pain may depend on our relationship to that individual, the data might show that attention to pain expressions varies based on kinship or familiarity.

Several facial action units (AUs) are correlated with pain. These include lowered brows, raised cheeks, tightened eyelids, a raised upper lip or opened mouth, and closed eyes (Craig et al. 1991; Prkachin 1992b; Prkachin & Mercer 1989). However, it is not known which core AUs are most crucial, or most successful, in conveying pain. This can be studied with a forced-choice task in which two face images are presented side-by-side, and observers are asked to decide which face expresses the most pain. The faces display neutral expressions except for one or more superimposed element corresponding to a pain AU. By comparing which AUs, and which of their combinations, results in the highest pain rating, one can determine which AUs contribute most to an effective pain expression.

The human evolutionary response to the expression of pain can also be investigated. Subjects undergo the same procedure just described, but are asked to decide to which of the two faces they would more likely offer assistance. By comparing results from these subjects with results from the first, we can determine if faces that are most successful in expressing pain are also most likely to receive aid. Perhaps higher ratings of pain correlate with higher ratings of help. Even if they do not, the results can be analyzed to determine which pain AUs recruit the most human assistance. This might give insight to possible differences between perception of chronic and acute pain, since some AUs may be correlated more highly with one type of pain than another.

Previous studies of eye-movements indicate that we employ different patterns of fixation for different facial expressions. For example, when human observers view smiling faces they more often fixate on the corners of the eyes (Williams et al. 2001). Apparently we subconsciously check for evidence of a "duchenne," or genuine, smile which causes crinkling of the folds around the eye. A merely social smile lacks these crinkles. As with the smiling face, we may also have evolved to subconsciously fixate on certain key features when viewing a face in pain. Results from eye-movement studies can reveal which features we fixate on initially and which most frequently, when viewing expressions of pain.

Although studies of eye movements reveal much about patterns of looking, they are not an infallible guide to the distribution of attention (Ballard et al. 1995; Hayhoe et al. 1998; Zelinsky 1997). A complementary approach is the flicker task from the field of change blindness (Rensink et al. 1995; 1997; Simons & Levin 1997). Although change blindness is traditionally used to investigate attention to scenes, recent studies show the flicker technique can be used to study attention to faces, and that faces engage specific endogenous, that is, meaning-driven, mechanisms of attention (Davies & Hoffman 2002). The flicker technique involves a brief presentation of one image (about 100–1,000 milliseconds), a blank screen (about 100 milliseconds), and then the same image again with one small change to the image. This sequence cycles until the observer detects the change, and surprisingly, it often takes a long time. One reason is that the blank screen prevents motion from directing attention to the change. As a result, observers must build descriptions of items in the scene one by one, store these in visual short term memory, and then compare these descriptions with descriptions built from the second image (Rensink 2000a; 2000b; 2000c). Items whose changes are better detected are items that are likely to have received more attention. In comparing change blindness results for pain and other expressions we may find differential patterns of attention, which may indicate different evolved mechanisms for processing, and ultimately perceiving, specific expressions.

By investigating human performance in the perception and detection of pain, we can learn more about subconscious processes that influence how we fixate on, react to, and interpret expressions of pain. By comparing these results to those for other facial expressions we can more clearly define the key attributes that make pain a unique facial expression for which we have evolved specific mechanisms of perception and action.

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Pain, evolution, and the placebo response

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Abstract: Williams argues that humans have evolved special purpose adaptations for eliciting medical attention from others, such as a specific facial expression of pain. She also recognises that such adaptations would almost certainly have coevolved with adaptations for providing and *responding* to medical care. The placebo response may be one such adaptation, and any evolutionary account of pain must also address this important phenomenon.

Williams argues that among the evolved human facial expressions there is a distinct facial expression of pain. The function of this state, she claims, is to elicit social assistance of a medical kind. The plausibility of this claim depends on how long medical care has been in existence.

Unfortunately, we are extremely ignorant about the exact age of medicine. It must have originated after the human lineage had already diverged from that of the chimpanzees, because chimpanzees do not practise medicine, if by medicine we mean the provision of special care to a sick individual *by others.* Primatologists have observed many cases in which chimpanzees take care of *themselves* when ill or injured, sometimes in quite elaborate ways, such as consuming plants with medicinal properties or dabbing leaves on bloody wounds, but they have never seen one chimp provide this sort of medical assistance to another. Chimpanzees do spend long hours picking the ticks off each other's backs, which could, perhaps, be regarded as a kind of preventive medicine, but *therapeutic* medicine seems to lie outside their behavioural repertoire.

Archaeological evidence of ancient medical practices does not appear until relatively late. Ancient texts from Mesopotamia and Egypt provide written evidence that sophisticated medical practices were well established by 1,700 BC (Porter 1997), but evidence of the existence of medicine prior to the advent of writing is much harder to come by. One rare example is the existence of skulls with small holes surrounded by calluses that indicate that trepanning was being performed in places as far apart as France and the Pacific by 5,000 BC. This is an operation which involves cutting a small hole in the skull and scraping away portions of the cranium. If such a complex operation was being performed 7,000 years ago, it is a fair bet that more primitive forms of medicine were being practised earlier, but how much earlier is hard to say.

We know, then, that medicine – the provision of special care to the sick by others – must have originated some time between five million years ago and 10,000 years ago. Of course, that is a very large time window. It is so large, in fact, as to leave us ignorant on the vital question of whether or not there has been enough time for natural selection to shape specific adaptations for medical care. If medicine originated towards the beginning of this window, shortly after the hominid lineage branched off from that of the chimpanzees, then there would certainly have been time for the human brain to have developed special purpose mechanisms for eliciting, providing, and responding to medical help. If, however, medicine only started towards the end of this time window, when our ancestors were already fully human, then there would not have been time for any such special-purpose medical adaptations to have evolved.

Still, even if we are ignorant on this point, we can still explore each of the alternatives. The first possibility is that medicine is a few million years old, and that humans have evolved special psychological and physiological mechanisms that are for eliciting, providing, and responding to the provision of medical attention. Williams concentrates on adaptations for eliciting medical care, in particular, on the facial expression of pain, but she also points out that such adaptations would almost certainly have coevolved with adaptations for providing and *responding* to medical care.

Williams draws on the work of the late Patrick Wall, particularly on his claim that pain is a "need state," like hunger and thirst (Wall 1999b). Need states are terminated by specific consummatory acts; hunger by eating, thirst by drinking, and so on. Pain, presumably, is no different. Withdrawing one's hand rapidly from a hot stove is a consummatory act that terminates one sort of pain; keeping a sprained ankle still is a consummatory act that terminates another. Crucial to Wall's argument, however, is that pain can sometimes be terminated simply by care and attention from others. It is this addition of a purely social event to the list of various consummatory acts relevant to pain that makes human pain such an evolutionary novelty.

Wall's claim about the relevance of social support to pain relief is supported by studies that have investigated the anti-inflammatory effects of fake ultrasound (Hashish et al. 1986; 1988). One of these studies found that the placebo response was only triggered when the fake ultrasound was applied by *someone else.* When exactly the same physical stimulus was applied by the patients to their own faces, the swelling was not reduced. This suggests that the mere provision of social support can be sufficient to trigger the placebo response. Perhaps this is the result of natural selection wiring up the pain generating circuits in the brain to inputs from the neural regions that are sensitive to social support. Of course, this presupposes that medical care has been a feature of our environment for long enough to enable such evolutionary change to take place.

If Wall's theory is right, and natural selection has designed specific brain circuits to feed information about the social environment into the circuits that generate pain, such circuits must confer some evolutionary advantage on those who have them. It is hard, however, to see what this advantage might be. As Williams points out, pain is a vital protective mechanism, and those who lack the capacity for pain do not survive very long. What possible advantage could there be in having a mechanism that shuts down pain when medical care is provided? Surely it would be better to make the sensation of pain autonomous, independent of such social factors?

Or would it? There are costs as well as benefits associated with pain (Humphrey 2000). In particular, high levels of pain can actually slow down the healing process. When you are alone, the protective value of pain might outweigh the disadvantage of slowing down the healing process, but when others are taking care of you, the cost-benefit ratio may change. In particular, when others can protect you, pain might not be so vital. In effect, medical care might allow the patient to offload the protective function of pain onto others: Self-defence is unnecessary when other people are around to do the defending for you. If this is true, then a person whose brain was capable of shutting down pain when it detected the presence of medical help might actually have an advantage over someone whose brain lacked this capacity (Evans 2003).

What is pain facial expression for?

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Abstract: A functional interpretation of facial expressions of pain is welcome. Facial expressions of pain may be useful not only for communication, such as inviting help. They may also be of direct use, as parts of writhing pain behavior patterns, serving to get rid of pain stimuli and/or to suppress pain sensations by something akin to hyperstimulation analgesia.

Williams defends the position that facial expression of pain belongs to pain behaviors generally, and is in some way functional in dealing with the pain. This position has proven fruitful for the study of facial expressions generally (Frijda & Tcherkassof 1997).

Since Darwin, facial expressions are viewed as functional primarily because they communicate information on the subject's state to onlookers, who may come to the subject's assistance or fulfill his or her desires. For Darwin, facial expressions were, in part, serviceable habits that survived in evolution because of the benefit for survival that their communicative value brought. It is along the same lines that Williams interprets the use of facial expression of pain.

However, there is no reason to assume that the serviceable habits have entirely lost their original significance. In fact, some of Darwin's interpretations are based on contemporary, as well as on ancient, advantages. He interpreted the obliquely drawn eyebrows of fear as a consequence of protecting the eyes under threat, and at the same time keeping them open in order to keep seeing the threat. There is no reason why this mechanism would not be operative in fear expressions in humans today, even if the automatism also occurs when the habits are of no use, such as when listening to a fearful story.

Some facial expressions are obviously functional in this sense. One example is the protective startle response; another is the facial aspect of the orienting reflex that includes one element of the standard facial expression of surprise, namely, eye-widening. Eye-widening in orienting and surprise probably broadens the available visual field, and may also facilitate eye movements.

Facial expressions of pain may well have a utility that is quite distinct from their communicative value. Facial expressions of pain are part of more encompassing pain behaviors such as stretching and throwing the head backwards, or contracting, drawing in the shoulders, and bending the head and torso. They accompany overall tensing of the limbs, clenching the fists, or other spasmodic movements. All these behaviors can be plausibly seen as part of an overall behavioral pattern of writhing or squirming. Facial expressions of pain appear to be part of a rather elementary pain response of writhing, which would seem to serve the function of getting rid of the painful stimulus. It might also serve to diminish the pain sensation by diverting attention or by suppressing the pain sensations. Clenching one's teeth illustrates that latter function, as does digging one's nails into one's palms.

The facial contortions of a person in pain would seem to contribute little to the escape or suppressive functions of body contortions and tensing elsewhere in the body. However, there are muscular synergies that induce movements that are of no use. A distinct example is given by facial expressions accompanying muscular effort; the expressions strongly resemble those of pain. Take the faces made when pulling a rope or lifting a heavily laden spade; or that facial expression of no obvious communicative value: the facial expression of efforts made during bowel movements. All this corresponds more to Darwin's third principle, that of the irradiation of nerve-force, but it is still serviceable as part of exerting force, given a certain crudeness of motor control.

Darwin implied that pain behaviors with such a function would only be retained in evolution when they were actually of use. I am not sure that current evolution theory requires the merely useless action dispositions to spontaneously disappear. But even so, is there evidence – other than everyday self-observation or illusion – that the mentioned pain behaviors are indeed of direct use by increasing pain thresholds? There may well be. It would be consonant with the gate-control theory of pain, and with the research on hyperstimulation analgesia (Melzack 1973); but whether this includes systematic research on the effects of muscular effort, wriggling, and facial pain expressions, I do not know.

It would be useful to know whether facial expressions of pain differ from facial expressions of muscular effort, and not merely from other expressions of emotion. If they do, it would strengthen the hypothesis of communication function; if not, it would strengthen a hypothesis of direct use.

In any case, this possibility of direct uses of facial expressions only adds to the plausibility of Williams' general point: that facial expressions of pain have a nonoperant, evolutionary origin.

Intention and authenticity in the facial expression of pain

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Abstract: Williams and the many studies she considers appear to assume that voluntary amplification in facial expression of pain implies dissimulation. In fact, the behavioral ecology model of pain expression is consistent with amplification when subjects in pain are in the presence of others disposed to render aid, and that amplification may well be voluntary.

Block et al. (1980) and Flor et al. (1995) show that subjects exhibit an increase in pain behavior in the presence of solicitous others, such as family members, and healthcare professionals. It may be

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tempting to see these studies as showing that subjects in pain tend to exaggerate their pain expressions in order to derive more aid than their degree of suffering requires from those in a position to provide aid. However, these studies need to be considered alongside those of Kleck et al. (1976) and Badali (2000), who show that pain expression is greater among subjects who believe themselves to be unobserved, than when they believe themselves to be observed by neutral onlookers.

Williams suggests the data shows that the increase in pain behavior in the presence of those in a position to render aid is not due to amplification (and presumably, to that extent, to dissimulation – however, see below), but rather to a "release of suppression of pain expression, rather than its amplification"(target article, sect. 7). Part of the background of this thought is that a manifestation of pain incurs a risk because it can give a cue to antagonists to press their advantage. Thus, from an evolutionary perspective it would be beneficial to suppress our expressions of pain in the presence of others, unless we take them to be disposed to render aid. In that case, we do not inhibit or suppress our pain expressions but let them flow naturally. According to the present line of thought we also let those pain expressions flow naturally when we take ourselves to be unobserved, for in this situation there is evidently little risk of betraying vulnerability.

Williams' hypothesis would be confirmed if it were established that pain expression in the presence of those capable of rendering aid is approximately the same as that exhibited by those who take themselves to be unobserved. In both cases subjects' facial expressions would be explicable as a release of otherwise suppressed pain behavior. I am aware of no studies confirming or disconfirming this hypothesis. However, suppose it turns out that pain behavior is greater among subjects who are in the presence of those they take to be capable of rendering aid than it is when they take themselves to be unobserved. That might seem to undermine Williams' hypothesis, but in fact I shall argue that it would not. Further, many of the studies Williams reviews appear to assume that only involuntary facial expressions of pain can truly reflect a subject's level of suffering; that where there is intervention of the will in the production of pain behavior, so there is likely to be dissimulation. This is a *non sequitur*. I argue for these points in turn.

Williams cites Fridlund's (1994; 1996; 1997) behavioral ecology model of facial expression as emphasizing the coevolution of facial displays and vigilance for them. A consequence of this is an emphasis not on just the morphology of facial displays of such states as pain, but also on the ability of others to detect that expression. It behooves antagonists to detect such expressions because doing so helps them to discern when to press their advantage. It behooves allies to detect such expressions because doing so allows them to determine when aid is required, as well as to be alert to potential danger (which may be the source of their allies' pain). However, it is consistent with the behavioral ecology approach that in the presence of certain kinds of audience, agents would exaggerate their facial expressions. As Fridlund makes clear, facial expressions should be construed as essentially signals. Therefore, if we have an evolved propensity to express pain to solicit aid we should also have a propensity to do so in such a way that the message thus sent is decodable with relative ease. It would therefore be intelligible that we might have an evolved propensity to caricature, or at least exaggerate, our pain expressions for the sake of communication (Fridlund 1997, p. 106). By contrast, in the absence of an audience, our propensity would merely be to disinhibit those expressions with no exaggeration. After all, those potentially able to render aid might not be close enough to detect unamplified changes in our face; while being in pain, we might also be in rapid motion, or there may be other environmental sources of noise. As a result, a difference in pain expression – in response to the same kind of irritation – between that in the presence of a potential helper and that in private, need not prove dissimulation on the part of the subject. Instead, it may be the result of an evolved propensity to ensure relative ease in the decoding of signals.

Exaggeration or caricature of pain expression in the presence of certain others may of course be an involuntary response triggered by contextual cues. However, given our current state of knowledge, it is at least as likely that such amplification is voluntary, albeit behavior to which we might nevertheless be disposed by evolved mechanisms. (This involves no contradiction. Fleeing from a source of danger surely results from an evolved propensity, but is nevertheless in most cases done voluntarily.) Involuntary behavior can be a result of culturally acquired display rules (Matsumoto & Lee 1993), or innate predispositions, and in either case the result might be to give an organism a "default" to suppress pain. As a result, a voluntary contribution to facial display of pain might serve to correct a tendency due either to genetic or cultural pressure – to minimize that expression in order to foster communication for potential providers of aid. In either case the contribution of the will *increases* veracity rather than decreasing it.

In taking this view we need not follow Fridlund's suggestion that there is no real difference between sincere and insincere displays (Fridlund 1997); it can be held with no tension that some displays are dissimulating while others are not. Similarly, we need not hold with Fridlund (1994; 1997) that because facial displays are signals, they are not also readouts of internal affect. As Ekman (1998) remarks in response to Fridlund, there is no contradiction in their being both at once. What this view does mandate is a realization that the intervention of the will need not prevent a facial display from being a manifestation of a subject's internal state. When the will intervenes either to counteract the influence of display rules or inherited defensive dispositions, it does not detract from, and may even enhance, the authenticity of the display.

Pain facial expression: Individual variability undermines the specific adaptationist account

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Abstract: The proposal that there are specific adaptations for the expression and detection of pain appears premature on both conceptual and empirical grounds. We discuss criteria for the validation of a pain facial expression. We also describe recent findings from our lab on coping styles and pain expression, which illustrate the importance of considering individual differences when proposing evolutionary explanations.

We applaud Williams' goal that pain be adequately recognized and treated, and her cross-disciplinary synthesis of several literatures. However, there are pitfalls to such an effort, and the fit between her theory and the empirical findings appears questionable.

Williams argues that natural selection shaped specific adaptations for the production and decoding of pain expressions. According to her logic, the inclusive fitness benefit to the sender is the receipt of succor from conspecifics, while the benefit to the observer is awareness of potential dangers. Logically, this would require that the facial expression of pain be clear and distinct from other emotional expressions and that observers be able to reliably detect such expressions. Therefore, pain action units (AUs) must be: (1) co-occurring; (2) evident among some percentage of subjects; (3) elicited by a variety of pain-evoking stimuli; and (4) differentiated from other expressions. Williams does not analyze the most relevant data (frequency, percentages of subjects displaying each AU, co-occurrence of AUs), which are essential in evaluating the robustness of a proposed pain expression. Also problematic is that people are poor at reliably detecting another's pain and do not necessarily rely on the AUs implicated in the proposed pain expression (e.g., nasolabial furrow [AU 11]; Chambers & McGrath 1998, as cited by Williams).

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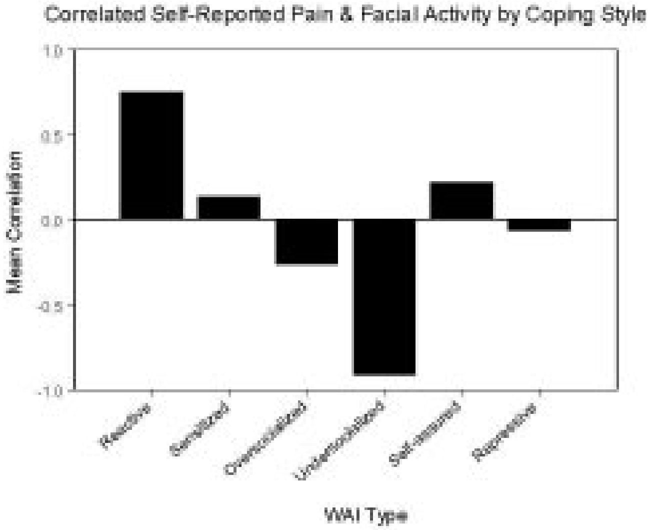

Figure 1 (Harris & Alvarado). Correlated self-reported pain and facial activity by coping style

To address these difficulties, Williams proposes selective pressures for the detection of faked pain expressions to prevent "social cheating." As evidence, she points out that physicians with incentives to avoid unnecessarily prescribing analgesics are particularly prone to underestimate pain. This illustrates a general weakness in her theoretical approach, namely, insufficient consideration of other possibilities besides operant behaviorism and evolutionary psychology. It is gratuitous to propose specific adaptations for behaviors that would be expected to emerge from general processes of means–end problem solving (Harris & Pashler 1995). People are alert to cues that are relevant to their goals and interests in many different domains, including activities that only emerged in recent human history and for which no specific adaptations could exist. To achieve their goal of accurate diagnosis, health care professionals must be able to detect misleading pain expression; hence, they will develop strategies for doing so (whether valid or invalid). There is no need to invoke "evolved propensities or inference rules" for detecting pain or the dissimulation of pain to explain this, and such behavior may have little to do with the types of "social contracts" that occurred in the Pleistocene era.

From Williams' review, the pain expression appears subject to the same complexities as emotional expression. Like emotional expressions (Alvarado & Jameson 2002), pain expressions are reliably decoded only when extreme, and they convey amplitude of experience poorly. Their interpretation varies with context and can be biased by suggestion. Pain expressions are influenced by display rules, and show large individual differences in both production and decoding. As with emotional expressions, the relationship between facial activity, physiological response, and self-report is poorly understood and difficult to demonstrate. These similarities suggest that pain expressions belong to a more generalized phenomenon of facial expressive behavior best studied together with, and in the same manner, as emotional expressions. Such work demands greater rigor than is usually possible in clinical or naturalistic settings.

Williams shows little recognition of the controversies among those studying facial behavior. She claims that the Facial Action Coding System (FACS) cannot be used to record durations, onset or offset times, asymmetries, co-occurrence of AUs, or other subtleties present in dynamic stimuli. Studies by Ekman and Rosenberg (Ekman 1997a; Ekman & Rosenberg 1997) contradict this assertion, as does the FACS manual. Williams overemphasizes the potential impact of posing, deception, anxiety, and embarrassment on the behavior of lab participants. In this, she uncritically accepts arguments raised by critics of Ekman's approach (Russell & Fernandez-Dols 1997), without showing that they matter in the empirical studies reviewed. Such "methodological" criticisms, if valid, work against her argument: An expression so fragile as to be disrupted by subtle lab-induced anomalies cannot have evolved a survival-related meaning sufficiently reliable to be useful in clinical situations.

What else can be made of the empirical work reviewed in Williams' article? Her proposed pain expression includes "lip corner stretch" (AU 12), better known as a smile in other contexts. Is this a grimace, or help-seeking through ingratiation? If a pain expression communicates to conspecifics, then perhaps it arose not during threat or trauma but as a means of keeping rough-and-tumble play from becoming dangerous. It may signal "stop hurting me," not "help me." Its intensity may reflect the message's urgency, not the amount of pain. Its appearance during other injury may be incidental to this more frequent scenario.

Williams acknowledges that no gold standard exists for measuring pain, and then uses self-report as the measure of accuracy for those judging facial behavior. We suspect the relationship between self-report and expressivity is too complex to be explained by physician bias. In our research, we classified individuals using the Weinberger Adjustment Inventory (WAI) (Weinberger 1990; 1997; Weinberger & Schwartz 1990) and found that the correlation between facial expression and self-report varied with coping style (Alvarado & Harris 2003; Harris & Alvarado 2003). Figure 1 shows the mean correlation by WAI type between scores on the McGill Pain Inventory (sensory scale) and facial activity.

No significant differences in either measure were found across WAI types (ruling out amplification or suppression by type), but correlations between the two varied considerably. This is obscured in many studies, where a low mean correlation typically emerges from the averaging of divergent patterns. Those highest on Weinberger's restraint scale (repressives) showed the least correlation, suggesting idiosyncratic control of facial expression. The oversocialized and undersocialized subjects both showed an inverse correlation, smiling or grimacing while reporting little pain. These findings suggest that facial expression is difficult to interpret without knowing a person's habitual coping style, knowledge normally inaccessible to clinicians. Perhaps an increase in expressivity when others are present results from a switch from emotion-focused or cognitive coping to reliance on social support. These individual differences suggest that clinicians should not consider facial expressions alone a reliable measure of pain, much less use them to determine medication dosages.

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Facial expression of pain – more than a fuzzy expression of distress?

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Abstract: Facial expressions of pain may be best conceptualized as an example of an evolved propensity to communicate distress, rather than as a distinct category of facial expression. The operant model goes beyond the evolutionary account, as it can explain how the (facial) expression of pain can become maladaptive as a result of its capability to elicit attention and caring behavior in the observer.

There is little doubt that it is the merit of the operant model to acknowledge that pain is communicated and that this communication elicits a response in the observer, which, in turn, can contribute to the maintenance of pain. Although 25 years have passed since Fordyce (1976) formulated the operant model of chronic pain, remarkably little is known about the emotional and motivational information of nonverbal and paraverbal pain behaviors conveyed to the observer.

While pointing out the significance of nonverbal and paraverbal communications of pain, the operant model does not provide a theoretical account of the nature of the (facial) expression of pain. It is the core assumption of the operant model that the expression of pain is shaped by contingencies. Yet, this assumption does not preclude an evolutionary basis of pain communication. In fact, the central tenet of the operant model is very similar to the assumptions of emotion researchers in that the expression of primary emotions follows *acquired* display rules (i.e., the learning of discriminative stimuli). This implies that the expression of pain, like emotional expressions, constitutes an unconditioned (and possibly evolved) response that can be brought under operant control and will be shaped by it. Therefore, the contingencies, such as positive or negative reinforcement or punishment, modulate the expression of pain, rather than the facial expression of pain (un)deliberately manipulating the contingencies.

For example, sequential analysis has demonstrated that solicitous and aggressive spouse responses systematically precede and follow patients' pain behaviors, thus exerting a significant amount of control on the frequency and intensity of pain expression above and beyond the subjectively experienced level of pain (e.g., Romano et al. 1992). Moreover, observed solicitous spouse responses have been found to predict the patients' level of physical disability (Romano et al. 1995). Whether expressed pain is exaggerated, or results from a release of its suppression, is not an issue for the operant model because this model's main concern is the functional role of pain behaviors in maintaining pain. The expression of pain (genuine or exaggerated) can become dysfunctional because, in chronic pain states, there is no longer a healing process that requires regular attention. Because of its nature to attract attention and solicit help, the expression of pain is likely to invite responses from observers that are adaptive in the acute stages of pain, but maladaptive in the longer run. Therefore, the evolutionary approach and the operant model do not necessarily contradict each other with regard to the presumed function of pain expressions to elicit help and care from the observer.

The operant model, as well as the evolutionary account, assumes that the facial expression of pain is *not* a direct, automatic, and reliable communication "device," but rather, represents an unconditioned (and possibly evolved) behavior controlled by display rules. Hence, the specific and additional contribution of an evolutionary perspective in explaining pain phenomena, and especially how pain becomes chronic, remains somewhat elusive. The operant model allows specific hypotheses about why and when pain behaviors, including the facial expression, can promote the development of chronic pain, and hence, it goes somewhat beyond the evolutionary approach. Furthermore, it is not only the evolutionary perspective that acknowledges the importance of cognitive, emotional, and motivational dimensions, and addresses the problem of pain within its social context. Comprehensive models of chronic pain, such as the psychobiological model (e.g., Flor et. al. 1990), or the cognitive-behavioral approach (e.g., Novy et. al. 1995), have argued for a multidimensional perspective on (chronic) pain for many years.

Some fundamental problems also remain with regard to the criteria (i.e., distinctiveness and detection by others) that need to be fulfilled for considering facial expressions of pain as a *distinct* evolved propensity. To begin with, there is quite limited empirical evidence for the existence of a pain-specific facial expression. When people are in pain, their faces may express a blend of emotions including fear, anger, disgust, surprise, and so forth, reflecting a fuzzy emotional state of distress and discomfort, rather than expressing the specific experience of pain. As illustrated in Table 1 of the target article, there is a great overlap between pain and other emotions with regard to the activated facial action units (AU), which challenges the suggested specificity of certain facial AU (e.g., lip corner pulled) as characteristics of a facial expression of pain. It would have been interesting if the facial AUs for disgust and surprise had also been provided in Table 1. Another problem arises from the assessment and coding procedures. In most, if not all, studies videos were used; that is, the raters or observers made their judgments based on changes in facial activity over time. By contrast, the vast majority of studies focusing on prototypical expressions of the primary emotions have relied on photographs. Is there a pain-specific facial expression that can be captured without relying on dynamic patterns of facial activity?

Moreover, it is not clear how good observers really are at detecting pain and gauging its intensity. In most studies the observers were not only directly asked to estimate the level of pain of the subject, but they also knew that the subject might have experienced pain, because, for example, he or she was undergoing a painful procedure. Would observers be able to tell whether someone is in pain rather than simply being in distress, if they did not have any contextual information or a priori expectations? To the best of our knowledge, there is no study that has tested whether subjects are able to detect and recognize the expression of pain without prior priming to consider pain as an option, or in comparison to primary emotional expressions.

It is certainly true that the nature of the communication of pain has not received a great deal of attention by researchers, despite the fact that the operant model, as well as subsequent, more comprehensive models of pain strongly emphasize the importance of the social context for the experience of pain. What all models would probably agree upon is that facial expression of pain serves the inner-species communication of one's emotional state, and in that sense, constitutes an evolved propensity. To what extent facial expressions of pain are distinct and provide information that is more specific than simply conveying a state of distress and discomfort remains to be seen.

Continuity and change in infants' facial expressions following an unanticipated aversive stimulus

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Abstract: I agree with Williams that evolutionary theory provides the best account of the pain expression. We may disagree as to whether pain has an emotional dimension or includes discrete basic emotions as integral components. I interpret basic emotion expressions that occur contemporaneously with pain expression as representing separate but highly interactive systems, each with distinct adaptive functions.

There is much agreement between Williams' conceptual framework for understanding pain and pain expression, and that represented in differential emotions theory (Abe & Izard 1999; Izard 1993; Izard & Ackerman 2000) and related research on infants' facial expressions to nonpainful stressors and painful stimulation (Huebner & Izard 1988; Izard et al. 1983; 1987; Shiller et al. 1986) We agree that evolutionary theory provides the best account of the function of the pain experience and the pain expression. I am not sure if we disagree on the issue of pain-emotion relations, because I did not discern a clear stand by Williams on this issue. Possible differences on the pain-emotion issue may stem from my adherence to differential emotions theory and my use of it to interpret data on the ontogeny of pain and emotion expressions. For example, our research with young infants suggests that in addition to eliciting the pain expression, unanticipated pain is an innate activator of anger, and that pain anticipation elicits fear and possibly other emotions.

Pain-emotion relations. In her discussion of the functions of pain, Williams acknowledges the importance of recognizing a difference between sensory-discrimination and affective-motivational processing of pain by the brain. Yet, she was not explicit as to whether her evolutionary account of the pain experience and pain expression rejects interpretations of pain as an emotional phenomenon. The issue here is whether pain (1) includes anger, sadness, fear, or disgust as an integral component, or (2) immediately recruits one or more of these basic emotions. Put another way, we can think of pain as an emotion or as a negative affect having emotional aspects, or we can think of pain and each of the basic emotions as separate modular systems that can function with some independence (Ackerman et al.1998; Izard 1993; LeDoux 1996). Tomkins (1963) has discussed several features of emotions that distinguish them from pain and other affects traditionally considered as drives. For example, the specificity of causes for, and behavioral responses to, pain is much greater than that for any basic emotion.

In contrast to pain, each basic emotion serves as a general-purpose motivational system, with a virtually limitless variety of activators and associated behavioral responses. Whereas pain evolved as an adaptation to a very specific type of contingency (injury or other physically aversive stimulus), each basic emotion evolved as an adaptation to a wide range of stimuli. If we assume the modularity and relative independence of pain and emotion systems, we might find new ways of explaining why different emotion expressions appear along with pain expressions. Such a conceptual framework suggests that we consider the possibility of distinctly different adaptive functions for both pain and basic emotion expressions in response to painful stimulation. It also suggests that nonpainful and painful stressors will produce different patterns of facial expressions.

Developmental studies of facial expressions. Studies of infants' facial behavior in response to nonpainful stressful events, and to an acute and unexpected painful stimulus, provide data relevant to the issue of pain-emotion relations and the related issue of contemporaneous pain and emotion expressions. In these studies, we used an anatomically based micro-analytic coding system called Max (Izard 1979) to measure facial behavior. An appearance change (AC) coded with Max is comparable to an action unit (AU) coded with FACS (Ekman & Friesen 1978). We identified the pain expression by Max codes that reveal the following: brows drawn sharply downward, a bulge between inner brow corners, nasal root broadened, eyes tightly shut, and upper and lower lip movements give the mouth a square-like or rectangular shape. The regularity with which we observed this configuration in young infants, very similar to that described by Darwin (1872/1965, p. 147) and by Williams, led us to conclude that it represented the prototypical human pain expression. Differences from this configuration emerge from the interplay of the maturation of brain inhibitory systems on the one hand and cognitive development, cultural attitudes, and socialization on the other. Some of the same muscle movements in the ACs of the infant pain expression would make different ACs in adults. For example, the corrugator action that makes the bulge between infants' brows and broadens the nasal root might make only vertical furrows in adults. The difference is due to the relatively greater amount of superficial fatty deposits in infants' faces.

Facial expressions to nonpainful stressors and painful stimulation. The negative facial behavior of 13-month-old infants in response to the stressful episodes of the strange situation procedure, consisted almost entirely of expressions of anger and sadness (Shiller et al. 1986). The infants did not show expressions of pain. In contrast, facial behavior during the first 10 seconds following diptheria, pertussis, and tetanus (DPT) inoculations at approximately 2, 4, and 7 months of age revealed that 41 out of 45 infants quite uniformly displayed the pain expression immediately following needle penetration. At 19 months only 30% showed the pain expression as the first and immediate facial expression, but 70% displayed it during the 10-second interval. The rest showed anger most of the time, along with brief expressions of sadness. Anger was by far the most frequently co-occurring expression.

A separate longitudinal study followed 25 infants from the first DPT inoculation at 2 months-of-age to the fourth inoculation at 19 months. The findings confirmed those of the first study, and in addition, showed both group changes and individual stability in patterns of facial behavior over time. As a group, the infants showed marked age-related changes in the amount of time they displayed the different expressions, particularly, a decreased amount of time for pain and an increased amount of time for anger. As individuals they showed considerable consistency in the amount of time they displayed expressions of anger and sadness over time.

Interpreting the patterns of facial expressions to painful stimulation. The healthy infants in our studies never showed pain or emotion expressions in *anticipation* of the DPT inoculation. They often smiled at the nurse and even attempted to grasp the syringe if the nurse playfully offered it to them. They did not remember the preceding inoculation. *Anticipated painful stimulation* would elicit a different pattern of responses. During informal observations, we noted that young infants of eight or nine months, whose health status required frequent invasive procedures, showed conditioned fear responses to the nurse and even to the sight of the clinic as they approached it.

Williams' version of an evolutionary account of the pain expression is based on the assumption that pain is an emotion and contains other emotions or emotion expressions as integral components. Our assumption that pain and each of the basic emotions represent relatively independent, but highly interactive systems, has different implications for interpreting the discrete emotion expressions that occur contemporaneously with pain expression. Considering the different emotion expressions elicited by painful stimulation as reflecting different emotions and motivations, may strengthen an evolutionary account of pain, pain-induced expressions, and coping behaviors. A pattern of pain and basic emotion expressions in response to injury provide an adaptive advantage over a pain expression alone. The infant's pain expression is an all-out emergency response. It dominates neural processes, preempts all the infant's affective, cognitive, and action systems, and allows no cognitive or behavioral alternatives (Emde et al.1976; Izard et al. 1987). In relation to Williams' discussion of partial control of pain expression, we saw no evidence of control or other coping activity in the first half-year of life. However, the shift at about seven months toward less time in the all-out pain expression (emergency response and more time in anger expression) may indicate a significant change in affect communication, the beginnings of the self-regulation of the pain expression, and a gateway to coping alternatives. Might adults' expressions of emotions during pain have a similar significance?

Whereas the pain expression represents the infant's maximum effort to influence the environment and compel someone to come and change what's happening, the basic emotion expressions that occur in infants' responses to painful stimulation serve distinctly different functions. For example, the expression of sadness is a stimulus for empathy and helping behavior. The expression of anger signals protest against the aversive condition. If we assume that emotion motivation accompanies the emotion expression, then we can also consider other adaptive advantages. Anger arousal marshals energy for defensive actions. Sadness has a slowing effect on cognitive and motor systems that facilitate information processing that may lead to improved communication with potential helpers (Izard & Ackerman 2000; Tomkins 1963).

Whether or not there is expression-feeling congruence for emotion expressions during pain, an evolutionary account of pain expression needs to take full advantage of the explanatory value of the adaptive functions of contemporaneous expressions of discrete emotions. It is adaptive to display sadness and anger in response to painful stimulation. At the same time, it seems equally adaptive for observers of the person in pain to decode these expressions as signals of sadness and anger rather than simply as additional signals of pain. A perception of a baby that is both hurting and sad makes a more compelling stimulus for comforting and helping behavior than a pain expression alone.

Sex differences in pain: Evolutionary links to facial pain expression

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Abstract: Women typically report more pain than men, as well as exhibit specific sex differences in the perception and emotional expression of pain. We present evidence that sex is a significant variable in the evolution of facial expression of pain.

Williams provides a timely and theoretically important contribution to the conceptual understanding of the role facial expressions of pain have in the perception, recognition, and treatment of pain. We wholeheartedly support Williams' argument that pain expression is unique, and that it serves an important evolutionary purpose in communication. However, the assumptions of universality preclude significant differences between the sexes. We would contest these assumptions and hypothesise that sex-related effects have lead to the evolution through psychosocial and biological routes of facial pain expressions. For example, there are important sex differences in nurturing behaviours, including the ability to quickly recognise and respond to distress in young. Mothers are typically more vigilant to signs of neonatal distress, and so should be more sensitive to facial expressions of pain. Our commentary, therefore, centres on the issue of sex differences in facial pain expression and recognition.

Sex differences in pain. There is considerable evidence that men and women differ in their perception and experience of pain (Berkley 1997; Berkley & Holdcroft 1999). Women typically report greater pain experiences, in that they are more likely to report a wider range of pains, in more bodily areas, and with greater frequency. Such sex differences not only occur in chronic pain, but also in acute pain states. It is generally believed that such differences are due to complex interactions between biological (e.g., hormonal), social (e.g., developmental), and psychological (e.g., emotion) factors (Fillingim 2000). Therefore, evolutionary forces acting on the complex psychobiological systems that manifest as sex differences in pain, may explain the mechanisms of the variations and alterations in facial pain expression and recognition between the sexes.

Facial expression, sex differences, and pain. Evidence suggests that there may be important differences in the facial pain expressions of males and females. In particular, females express more emotional displays than males (Brody 1985), and one of the main presentations of nonverbal communication is through facial expression. For example, blushing is the inheritance of an acquired habit (Darwin 1999); it is more common in women and may be a signal indicating emotional distress. Oestrogens initiate these effects through nongenomic vascular responses, but sex-steroid hormone expression can be limited genomically (Miller 1999). Thus, sex-related control over facial skin colouration might be modulated by evolutionary changes to an environmental stressor, such as pain. It would also be interesting to consider the evolutionary significance of the sex specific application of make-up, and whether this is used to manipulate facial signals, including those related to pain.

There are also developmental aspects associated with the differentiation in facial expression between the sexes, with both neurological maturation and environmental factors (e.g., socialisation) being implicated as key factors (McClure 2000). Regarding pain expressions, Guinsburg et al. (2000) found that amongst neonates, girls present greater facial pain displays than boys. Sex differences in facial expression are not just due to social inhibition, since infants who have arguably yet to be socialised into their respective sex roles also show this pattern of effects (McClure 2000). One possible explanation why females would express greater facial pain than males is linked to Berkley's (1997) argument that the greater susceptibility to pain-related disease may have led to the development of sex-specific differences in the detection of potentially harmful situations. The greater tendency for females to nurture may have also led to increased harm avoidance, and so to greater pain-related communication behaviours, such as through facial expression. In light of this, we generally expect sex differences to be found for facial expressions of pain.

Recognition of facial expressions of pain and sex differences. Evidence indicates that sex differences exist in the recognition of nonverbal cues or communication, including facial expressions (Hall 1984). Females are generally better at decoding nonverbal cues, and therefore better at recognising emotions. Additional proof derives from the neurological basis of negative expression recognition. The amygdala, a structure central to the expression and recognition of fear, demonstrates anatomical differences (Killgore et al. 2001). Interestingly, sex differences have also been found in the degree of opioid release in the amygdala during pain, with men showing more opioid release (Zubieta et al. 2002). Whether the two are related is currently unknown. Therefore, we believe that sex-specific differences in the recognition of emotional expression can be linked to sex differences in the recognition of facial pain expressions. From an evolutionary perspective, adult females may be more sensitive to negative expressions, including facial pain, through evolved differences in nurturing behaviours (Kelley 1988). Therefore, we would expect females to show a greater response to the nonverbal cues of infants in pain and distress, because it pays for mothers – whose maternity is guaranteed – to be sensitive towards expressions of pain and distress in their offspring.

Sexual activation. Imaging of pain in humans has identified sex differences in association with the anterior cingulate cortex in experimental and clinical pain states (Berman 2000; Paulson 1998). The question of facial responses during sexual behaviour/attraction is not raised by Williams, but cannot be ignored. Fundamental evolutionary processes depend on procreation and selection of an appropriate mate through behaviours relating to parts of the body that demonstrate emotion. Williams acknowledges the close relation of pain to motor function, but when the controlling centres are influenced by sex hormone changes, then it is likely that sex will become a factor in the evolution of facial expression. Of relevance is a study by Levine and De Simone (1991), who found that if an experimenter was female, men reported significantly less pain compared to when the experimenter was male; women did not show these differences. It could be argued that sex differences in facial pain expression were one of the factors in this result, and that the evolutionary results of such preferences for women may be in the selection of a mate with a more advantageous pain response, that is, greater fitness. A more mundane example of women's facial expression (including attractiveness) evolving with changes in pain intensity is given by the application of facial make-up once pain is subsiding. The evolution of the behaviour that exploits sexually orientated facial make-up, as a signal to others that discomfort is subsiding, is well recognised in clinical practice, and is predominantly female orientated.

Conclusion. We have argued here that sex differences in the experience of pain may be intrinsically linked to sex differences in the expression and recognition of facial pain. We believe that although facial expressions of pain are distinct and universal, there are social, psychosexual, and biological mechanisms for the evolution of specific differences between men and women. We present a framework for understanding the communication of pain as it differs between the sexes through facial expression and recognition.

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Facial expression of pain: "Just So Stories," spandrels, and patient blaming

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Abstract: Facial responses to pain might be the result of evolution but Williams' interesting "Just So" story provides no convincing evidence for her hypothesis. Contrary to her hope, casting facial action in an evolutionary perspective will probably not reduce the common practice of health care professionals blaming patients for their problems; instead, it may discourage appropriate treatment.

Williams has done a thorough and creative job of assembling and integrating the extant data on facial expression and has shown that these data can be interpreted in evolutionary terms. She argues that such an approach could reduce the common and pernicious practice of blaming patients who have chronic pain.

However, Williams presents scant evidence that facial expression is the result of evolution and no evidence that patients would be better treated if facial responses were shown to be evolutionary. Williams alludes to the argument of Gould and Lewontin (1979) who have objected to "Just So Stories" in evolutionary psychology. "*Just So Stories*" as Kipling (1912) originally told them, are stories about characteristics of various animals and how they developed. For example, "How the Whale got his Throat" tells the story of how a shipwrecked sailor – when swallowed by a whale – created baleen by cutting up his shipwreck and making a grate in the whales' throats so that whales could not eat people. These fanciful stories are wonderfully entertaining, post hoc explanations that have as their justification the joy, not the scientific enlightenment, they bring to the reader.

Williams' evolutionary account of facial response to pain is a great story, but I could not find in it the evidence that facial responses to pain are of evolutionary origin. Williams sets up operant conditioning as the only logical alternative and shows that operant conditioning cannot explain the emergence of facial expressions to pain. Her dismantling of operant conditioning is well done, but unnecessary. Most people who have seen infants produce facial expressions of pain at one hour after birth, need no convincing that reinforcement is not the major element in the development of facial responses to pain. What is needed to make Williams' argument convincing is evidence that facial expressions have changed in response to evolutionary pressure. The argument that communication of pain has current survival value is well made by Williams, but is not sufficient to show this is how it developed. Darwin (1873) discussed "correlations of growth," and, even more eloquently, Gould and Lewontin (1979) pointed out that behaviour might develop as a side effect, rather than as a direct effect, of evolution. Gould and Lewontin (1979) borrowed the architectural term "spandrel," which refers to the triangular space created when an arch is placed in a rectangular wall. Spandrels are often the site of elaborate decoration. They point out that spandrels are the by-product of the development of arches. That is, they were not developed for themselves, but came along with the development of arches. Similarly many features that are attributed to evolution are simply the by-product of other evolutionary changes and not the product of evolution itself. Gould (1997) suggests that there are two main ways of determining if a feature is a primary result of evolution or a secondary by-product. The first way is by evidence of an actual historical order of events. So, in our case, we would want to know when facial action for pain arose in the evolution of humans. This is unlikely to be available, as there is not likely a fossil record of pain faces. The second method, which is more likely to be useful in the case of pain facial expression, but is still inferential, is to use current examples of anatomy and behaviour across species that are more or less close to humans in evolutionary terms. This method could yield an inferred historical record. For this we need extensive cross-species studies that, as Williams notes, are not available at this time.

My own, personal, anecdotal, observation suggests that many mammals, at least the domestic and lab animals, and many nonmammals do not have facial expressions for pain. The most interesting data would, however, be from the lower and higher nonhuman primates.

So the question remains: Are facial actions evolved, or just an accidental spandrel left over from chance factors? Williams suggests a possible candidate, namely the close proximity of the motor and pain areas of the human brain. At this time, it is unclear why humans use facial expression rather than relying on the more common vocal and other behaviours that other animals use to signal pain. The answer will likely never be answered definitively, but additional data might make the story more convincing.

If facial pain expression were evolved, would it make a difference to the management of pain? Williams seeks an evolutionary explanation for facial pain expression because she believes that an evolutionary approach will overcome the dominant operant approach. She suggests this approach is too frequently applied and overemphasizes the benefits or gains that patients have from pain, and disregards the costs that patients in pain must endure. She hopes to use an evolutionary approach to reduce the preoccupation that many clinicians have with malingering, and to combat the ignoring of patient complaints and the under-treatment of pain. I share Williams' concern about doctors blaming patients for their condition, and about the preoccupation with unjustified and untherapeutic search for malingering. An additional patient-blaming tactic is to ascribe psychological causes as the source of pain.

Williams does not explain how an evolutionary model will reduce patient blaming. Health professionals have, from ancient times, blamed patients for not getting better when treatments failed. Prior to the poorly applied, operant model that is currently used to blame patients, we had a poorly applied psychodynamic model that also blamed patients and emphasized secondary gain from pain. Of course our Freudian colleagues did not originate patient blaming. Prior to Freud, patients were blamed on grounds of moral weakness and before that, because of supposed possession by evil spirits. I believe that if facial reaction to pain were shown to be evolved, patients would continue to be blamed. Moreover, because of the general but erroneous perception that anything genetic cannot be modified by learning, it is likely that pain patients who did not get better would be seen to deserve blame because of their evolutionary inferiority; it is also likely that they would be denied the psychosocial treatments that have been shown to decrease disability and improve quality of life (Williams et al. 1966).

A behavior-analytic developmental model is better

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Abstract: Behaviorists accept, but go beyond, Williams' notion that there is an evolutionary origin to some unlearned pain behaviors. A behavior-analytic developmental model is a better fit for explaining the totality of pain behaviors. This model focuses on respondent-operant interactions and views much pain behavior as "mands" (i.e., demands). Behaviorally based explanations from the crying and social referencing literature support this model.

Virtually every behavior analyst would agree that facial expressions of pain probably have an evolutionary origin. Skinner (1969; 1984) wrote extensively on the phylogenic basis of many human

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behaviors and supported the notion of "unlearned" or "innate" behaviors in addition to learned ones. The main weakness of Williams' article is her misunderstanding of "behaviorism," as demonstrated by her following contradictory statements: "operant mechanisms act on unconditioned pain behaviors. But where the implicit assumption is of a *tabula rasa* at birth, operant mechanisms become the exclusive explanation for pain, invoked with minimal or no evidence" (target article, sect. 2). Unconditioned behaviors (responses) are, by definition, unlearned or innate. This contradicts Williams' second statement that behaviorists make the implicit assumption of a *tabula rasa.* Skinner long ago addressed this misperception of behavioral theory in responding to a similar misunderstanding made by Breland and Breland (1961) when he said: "And it is a myth. No reputable student of animal behavior has ever taken the position 'that the animal comes to the laboratory as a virtual *tabula rasa*'." (Skinner 1969).

While Williams asserts that she only takes exception with the way behavioral theory has been misapplied to the clinical treatment of pain, and accepts other aspects of behavioral theory in general, her call for an evolutionary prewired account of the facial expression of pain makes it clear that she sees little utility in behavioral accounts and treatments of pain behaviors.

However, the issues Williams raises are better addressed by contemporary behavior analytic approaches (Novak 1996; 1998; Gewirtz & Peláez 2000). Behavior analysis provides more consistent, parsimonious, and empirical explanations of the development of behavior signaling pain and other emotions that emerge as a result of ontogenic and phylogenic histories.

The available evidence on some specific pain behaviors, including facial vocal expressions, is that they have a phylogenic source. As noted by Williams, infant facial expressions serve many functions that logically would have adaptive advantages. Primary among these functions is to signal to caretakers the existence of aversive stimuli. Animals (including humans) are born with many reflexes that have an apparent functional advantage for the species. These behavior-environment relationships are seen, in behavioral theory, to be the result of environmental contingencies that have worked, distally, in the history of the species. In behavioral terms, we have an unconditioned response (e.g., grimace) to an unconditioned stimulus (e.g., pin prick, stomachache). Although, as Williams points out, there is no consensus as to what constitutes a facial expression of pain, several of its phenotypic traits appear to be universal.

In the history of the species, the function of pain facial expressions – as of other pain behaviors – would evolve if they provided defensive functions, such as signaling the presence of harm-producing stimuli (including internal stimuli like pain). This is particularly functional for species with young, including humans with infants, who have limited repertoires of self-defensive behaviors, and survival reflexes that disappear quickly. Fixed responses to fixed stimuli, however, have limited utility over the course of a lifetime, particularly among species having long lifespans and inhabiting varied species-typical environments. These conditions give selection advantages to individuals in species who could also change responses to stimuli, or learn. While pain reflexes to unconditioned pain stimuli remain potent across the human lifespan, both respondent and operant learning are relevant to the shaping of pain behaviors.

In respondent conditioning, a neutral stimulus (e.g., lifting the child's leg) occurring in close temporal proximity to the unconditioned pain stimulus (e.g., heel-stick) acquires a new function of being a conditioned stimulus that elicits pain behaviors (Goubet et al. 2001). Thus, eventually, just seeing a needle can make an infant cry.

Operant learning is the focus of most behavior-analytic approaches, as it is in Fordyce's operant model of pain behavior, which is at the center of Williams' criticisms. From a behavioral-developmental perspective, operant-respondent interactions are involved (Bijou & Baer 1961). Not only are pain stimuli unconditioned stimuli for reflexive pain behaviors, they are also primary universal negative reinforcers. That is, because of phylogenic contingencies, all members of the species are more likely to engage in behaviors that terminate, remove, eliminate, or avoid these aversive painful stimuli. Some of these negatively reinforcing consequences may be automatic, as when moving an injured limb relieves the pain stimulus. Other consequences may consist of socially reinforcing events, as when crying causes a parent to move a child's injured limb to a more comfortable position. In addition to the negative reinforcement resulting from terminating the pain stimulus, positive reinforcement for pain reporting behaviors may occur, such as when the mother kisses the scraped knee of the crying child.

Behavior analysts (Hayes & Hayes 1992; Michael 1984; Novak 1996) apply Skinner's analysis of verbal behavior to these situations where the behavior is maintained by the mediation of a speaker who understands the function of the speaker's behavior. Therefore, the operant function of much pain behavior is that of a "mand," or demand for removing the pain stimulus. As Williams suggests, both speaker and listener must be involved, but from a behavior-analytic stand, these behaviors are learned (Gewirtz & Peláez-Nogueras 1992a). Note that behaviors might have both respondent and operant components contemporaneously. The development of crying behavior, which has the advantage of bringing assistance from a greater distance than facial expression, follows this pattern of transition from respondent to operant crying. A cry of pain is among the universal distinctive cries of human neonates. Although pain crying is distinct, these differences are small (Fuller 1991), and parents (especially mothers) quickly learn to identify and respond to their own infants' pain cries (Wiesenfeld et al. 1981). The original respondent crying may be shaped into operant behavior reinforced by either positive or negative reinforcement. Operant crying may grow to be so problematic that it becomes the focus of clinical intervention (Etzel & Gewirtz 1967; Gewirtz & Boyd 1977; Hart et al. 1964). The effects of intermittent positive, social reinforcement by parents with regard to crying have been demonstrated in laboratory studies that explain the formation of infant attachment patterns to their mothers, and the conditioning of separation protests (Gewirtz & Peláez-Nogueras 1991).

Like Williams, Campos (1983) has postulated that the responses and perceptions comprising social referencing are "prewired" (i.e., unconditioned). As an alternative to that nativistic theory, Gewirtz and Peláez-Nogueras (1992b; Peláez-Nogueras 1992) demonstrated that infant social referencing results from the infant's contingency-based learning. That is, in contexts of uncertainty, maternal expressive facial cues of joy and fear come reliably to predict positive or aversive consequences for the infant's operant (reaching) responses. Using a conditioning-reversal (ABAB) design with eighteen 4- to 5-month-old infants who showed no social referencing, Peláez-Nogueras (1992) demonstrated that maternal emotional facial expressions can become conditioned cues for infant referencing. Initially, during pretreatment/baseline assessment, no difference existed in the incidence of infants reaching for ambiguous objects following either maternal joyful or fearful facial expressions. However, in the next phase, the infants learned to reach for ambiguous objects when reaching was cued by a joyful maternal facial expression and followed by extrinsic positive reinforcing consequences, and to avoid those ambiguous objects when reaching was cued by a fearful maternal expression and followed by extrinsic aversive consequence contingent on their reaching. In the third phase of the experiment this differential reaching pattern in the presence of the two facial-emotional expressions were extinguished. Finally, in the last phase, the cues recovered their predictive power when contingent reinforcement was reintroduced. These results supported the hypothesis that maternal facial emotional expressions serve as conditioned cues for infant social referencing and their reaching or avoiding responses in ambiguous contexts.

In the same manner, infants learn to use their mother's facial expressions as signals. One can easily observe the social referencing of toddlers who fall, look to their mother's face for a cue as to whether to get up and go on, or cry. In turn, the toddlers' facial expressions of pain are likely to serve as signals for the parents. These behaviors are subject to reinforcement by parents who typically relieve pain, and whose behavior is concurrently shaped by the child's termination of the grimaces and crying. Therefore, some long-term pain behaviors may be the result of direct pain stimuli, but they may also be the result of an operant history of reinforcing pain behaviors, as initially formulated by Fordyce.

In sum, the goal of behavior analysis is to identify the functional relationships between pain behaviors and their maintaining contingencies, both distal phylogenic and proximal ontogenic contingencies. We believe that the existing, well-established principles of behavior analysis are sufficient to account for the wide range of pain behavior phenomena. Compared with the evolutionary account proposed by Williams in the target article, we believe that behavior analysis provides both a more parsimonious account of the source of pain behaviors, and a more efficacious program for their clinical treatment.

"Mindscoping" pain and suffering

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Abstract: No adequate evidence exists for the evolution of facial pain expression and detection mechanisms, as opposed to social-learning processes. Although brain affective/emotional processes, and resulting whole body action patterns, have surely evolved, we should also aspire to monitor human suffering by direct neural measures rather than by more indirect indices.

There is probably no bigger issue for human and animal welfare than understanding and controlling pain and suffering. Amanda Williams has shared a wide-ranging evolutionary perspective on the sources of facial expressions that commonly accompany pain, and the associated psychological-communicative processes that, she suggests, may have evolutionary underpinning. It is an admirable call for more and better research, rather than a defining summary in a field where substantial evidence remains meager.

The practical issue is to develop external measures of internally experienced suffering, independent of pervasive social desirability and secondary gain issues that may affect outward emotional expressions. Williams favors the view that facial expressions function in a social-communicative role in addition to being an unconditioned consequence of the experience of suffering. Her approach leads to one clear prediction: Facial expressions of pain will be more evident in supportive social circumstances than in nonsupportive ones. Indeed, since Kleck et al. (1976) have found fewer facial expressions of pain in the company of others, Williams suspects that those effects are due to the presence of strangers, who might be prone to take advantage of the situation, rather than the presence of friends, who would be more likely to help. Williams suggests there are evolved communicative tendencies that regulate such expressions; hence, the issue of detecting lying and deceit becomes essential for her analysis.

We leave aside the conspicuous dilemma that the modulation of facial expressions by social context, including possible deliberate manipulations, *still* presents many problems for using facial expressions as a "gold standard" for evaluating the intensity and duration of affective experience, at least in adults. Instead, we will focus on critical evolutionary questions that Williams' perspective brings to the fore: Is there evidence to choose between evolution and learning as explanations for the regulation and detection of pain expressions? We think not. And even if certain such processes have been subject to some type of overall evolutionary pressures, we still have a long way to go to conclude that *individual* facial and perceptual components have been the objects of selection. Even as we respect Williams' struggles with such distinctions, we believe that most findings in evolutionary psychology, including those summarized by Williams, can at present be seen as largely reflecting learning-based processes – based perhaps on the reinforcing consequences of evolved affective processes, of which there are bound to be many.

Should we have any confidence in the assumption that "the pain face" evolved? Although Williams does not take a strong position on this, her extensive coverage of reliable pain action units could, without further clarification, be seen as an implicit acceptance that the expressions have undergone natural selection. Even though there may be substantial evolutionary underpinnings for many other facial expressions, such as smiling, which clearly facilitates certain social communications, one could easily suggest that the facial grimacing that accompanies acute pain may be part and parcel of a whole body defensive response (global flexor contraction) which may spill over into the facial musculature. From this perspective, pain may have highly predictable facial action units, without necessitating the conclusion that such expressions evolved in some ancestral deep time where the survival advantage of this or that face was penetrating into the genome. Williams herself asserts that evolutionary "selection operates at the level of function, not at the level of physical structures or behaviours that subserve the function" (target article, sect. 3). Perhaps for this reason, she focuses more of her efforts on the socio-cognitive rules that regulate facial displays, than on those that generate the displays.

We think it is quite reasonable to postulate that the *whole body* affect-linked expressions of pain have in fact evolved. This seems evident from the flailing and wailing of an infant in acute pain. Such responses are seen even in infant rats, whose facial expressions of pain would surely be lost on potential caretakers (albeit not their crying). Might not the facial accompaniments in creatures possessing the necessary facial muscles be evolutionary by-products of the global distress response, ones that can easily be molded by social learning, but by-products nonetheless? Therefore, while we accept that the global affective-distress response is surely evolved and full of internally experienced affective "meaning" for many animals, we would hesitate to accept the evolution of specific facial action units and related cognitive behaviors until simpler, more parsimonious affect-based learning interpretations have been evaluated and excluded.

In short, where evolution has generated global action patterns within the brain, the components of the patterns need not have been objects of selection with singular representations in the genome. Rather, they may be stable features of a general "instinctual" response tendency. We suspect there are many such broad-scale heuristic principles in mind/brain evolution, with the global responses generated by basic emotional systems comprising prime examples (Panksepp 1998). This is where modern evolutionary psychology may have already gone massively astray (Panksepp & Panksepp 2000). Although there are certainly various evolved emotional systems shared, in principle, by all mammals, the cognitive manifestations of those systems in their pervasive interactions with neocortical tissues that mediate general-purpose learning abilities may have few evolutionarily built-in strategies, except for conditional strategies to minimize distress and to maximize pleasure. The increasingly popular intellectual assumptions of mainstream evolutionary psychology are likely to remain in the realm of ideas and modest statistical trends, rather than of biological substance, for a long time to come. Most plausibility arguments in the area remain more heavily conceptual than empirical.

To take one final pain example – consider the phenomenon of limping. All vertebrates, when they have an injured leg, exhibit a limping gait that presumably has little, if any, intrinsic social communicative value. Either the limping reflects the effects of internally experienced pain on the central motor apparatus, or simply damaged peripheral structural supports. Very little about limping

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has evolved, with perhaps a few notable exceptions, such as killdeer that commonly mimic wing damage to protect their brood. Young children can surely increase their limping to obtain sympathy after an injury, or decrease it when faced with an unsympathetic audience. The killdeer's mimicry has presumably evolved; but is it wise to conclude that the human limping response has, as well? We certainly have social bonding mechanisms in our brain (Nelson & Panksepp 1998) that allow us to express many behaviors in the presence of those who care for us compared to those who do not, but should all those behaviors be deemed good candidates for evolutionary emergence? We think not. We encourage Williams to tell us what aspects of the existing *database* should coax us to be more receptive to evolved aspects of pain-related behavior.

Where does this leave us in our attempts to discern pain and suffering? As Williams asserts, this knowledge is of foremost importance in evaluating certain quality of life issues, but it is difficult to obtain. With spectacular recent advances in brain imaging, however, we do envision a day when pain and suffering can be brought under the lens of "mindscopes" that can tell us with more assurance whether a person's brain is truly beset by deeply troubling pain. This will require a better understanding of the affective pain pathways than we presently have, but we can already be fairly confident that one of the epicenters for basic affective experience of various kinds, including pain, is concentrated in certain neural systems such as those found in the periaqueductal gray (PAG) of the mesencephalon, and related midline areas of the brain (Panksepp 1998). However, even these brain areas are sensitive to various attentional and cognitive demands (Petrovic et al. 2000; Tracey et al. 2002). Visualization of these small and ancient brainstem areas can finally be routinely achieved with PET imaging (but not fMRI). Therefore, PET scans may offer an excellent objective standard against which self-report and behavioral measures (including facial expressions) can be compared. This may eventually yield robust and valid measures of the status of the affective pain circuits within the brain – and coming to terms with the deep neural nature of suffering is one of the main keys to better clinical practice.

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Machine understanding of facial expression of pain

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Abstract: An automated system for monitoring facial expressions could increase the reliability, sensitivity, and precision of the research on the relationship between facial signs and experiences of pain, and it could lead to new insights and diagnostic methods. This commentary examines whether the research on facial expression of pain, as reported by Williams, provides a sufficient basis for machine understanding of pain-associated facial expressions.

Automatic analysis of facial expressions is rapidly becoming an area of intense interest in Computer Vision and Artificial Intelligence research communities. The major impulse to investigate the machine vision problems of detecting, tracking, and interpreting human facial expressions comes from the potential benefits that could accrue from these efforts. Automated systems that sense, process, and interpret human facial signals have important commercial potential; they seem to have a natural place in commercial products such as computer systems for video conferencing, video telephony, video surveillance, face and visual speech synthesis, and pervasive perpetual man-machine interfaces. Furthermore, monitoring and interpreting facial signals are important to lawyers, the police, and security agents, who are often interested in issues concerning deception and attitude. Finally, basic research that uses measures of facial behavior including behavioral science, medicine, neurology, and psychiatry, would reap substantial benefits from inexpensive, reliable, and rapid facial measurement tools. Such tools could greatly advance the quality of research in these fields by (1) providing an increased reliability, sensitivity, and precision of facial measurements, (2) shortening the time to conduct research that is now lengthy and laborious, and (3) enabling many more researchers, who are presently inhibited by its expense and complexity, to use facial measurements. It is this potential improvement of basic research, including the research on the relationship between facial expressions and experiences of pain, that forms our major motivation to discuss here whether the research reported by Williams provides a sufficient basis for machine understanding of pain-associated facial expressions.

The problem of automatic facial expression analysis from images of faces is usually divided into three subproblem areas: (i) detecting the face and its permanent features such as eyebrows, eyes, and mouth in an input image; (ii) detecting the changes in the shape and location of the permanent facial features by making a comparison with an expressionless face of the observed subject; and (iii) interpreting these changes in terms of some interpretation categories such as the Action Units (AUs) categories defined in the Facial Action Coding System (FACS; Ekman & Friesen 1978) and/or in terms of affect-descriptive categories. For exhaustive reviews of the past attempts to solve these problems, the readers are referred to: Samal and Iyengar (1992) for an overview of early works, Donato et al. (1999) for a review of techniques for detecting micro facial actions (i.e., AUs of the FACS system), and Pantic and Rothkrantz (2000) for a survey of current efforts. The first two problem areas mentioned above concern issues typical for visual processing, and have, therefore, little relevance for this commentary. What is of interest here is whether the research reported by Williams provides well-defined rules, on the basis of which the facial expression of pain and its intensity can be distinguished from other facial expressions by using the currently available facial-expression processing technology.

From the previous work done on automating FACS coding, the automatic AU analyzers presented by Tian et al. (2001) and Pantic (2001) perform the best: They code 16 and 29 AUs, respectively, occurring alone or in combination in face images. Both systems can automatically detect AU4, AU6, AU7, AU9, AU10, AU12, AU20, AU25, AU26, and AU27, in terms of which Williams defines the facial expression of pain. In addition, Pantic (2001) proposes a self-adaptive facial-expression analyzer that classifies detected facial muscle activity into multiple, quantified, user-defined interpretation categories. By interacting with the user, the pertinent system is able to learn interpretations (e.g., "pain") that the user associates with different facial expressions. Nevertheless, some requirements must be met if a valuable automatic classification of AU codes into one or more quantified interpretation categories is to be accomplished.

1. *Each interpretation category must be uniquely defined* in terms of one or more AUs that underlie the facial expression characteristically classified in the interpretation category in question. The AUs in terms of which Williams defines the facial expression of pain are also micro components of facial expressions which are typically depicted as *"anger," "fear,"* and *"disgust"* (Ekman & Friesen 1975). In addition, the combination of these AUs is usually interpreted as *"disgust"* (Ekman & Friesen 1975), or more freely as *"loathing"* or *"yucky."* Hence, a unique definition of an "acute pain" interpretation category requisite for machine recognition of facial expression of pain cannot be obtained based upon the research results reported by Williams.

2. *The knowledge about the "influence" that each AU has* for

the produced facial expression to be classified in a certain interpretation category must be available. Based on this knowledge, quantification of an interpretation label generated by an automated facial expression analyzer can be accomplished. For example, does an activation of AU6 have the same influence as an activation of AU10, on the detection of pain by human observers? Williams reported that an observed patient can control the intensity and frequency of AU6 activation if he or she wishes to suppress or augment facial expression of pain. The same has not been reported for AU10. Hence, we can speculate that an evidence of AU10 activation should have more influence than an evidence of AU6 activation on the detection of pain by human observers.

However, this is mere speculation. A minimal set of AUs – their frequency, intensity, and overall temporal dynamics – and the relevant importance of each of those occurrences for human observers to detect pain, have not been clearly defined within Williams' report. Therefore, even if a unique "acute pain" interpretation category could be defined for the purposes of machine understanding of facial expression (see the discussion above), the knowledge needed to accomplish automatic quantification of such an interpretation label cannot be obtained from Williams' article.

In summary, the research presented by Williams does not provide clearly defined rules based on which facial expression of acute pain and its intensity can be distinguished from other facial expressions by an automated facial expression analyzer. The AUs in terms of which Williams defines the facial expressions of pain occur also in facial expressions interpreted usually as *disgust, anger,* and *fear.* The frequency of their occurrences, their intensity, and the related overall temporal dynamics relevant for detection of facial expression of pain either by human observers or by a computer system cannot be extracted from the target article.

Pain behavior and the pretence of knowledge

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Abstract: A monolithic model that ignores functional and topographic distinctions among its components has dominated clinical accounts of pain behavior. This model contributes to a pretence of knowledge that affects the treatment of sufferers. This commentary addresses the role of the target article in correcting knowledge-pretence and introduces a complementary *caveat* about evolutionary psychology concepts.

I was recently asked to assess a man who had been injured in an industrial accident. During rehabilitation subsequent to the accident, he developed a case of shingles. He was now presenting a complex pattern of pain complaints and disability of a sort that is all-too-familiar to clinicians who deal with those who suffer pain. Numerous clinical reports in the documentation I was provided with on this man drew special attention to his pain behavior. The documentation on this man suggested – and subsequent discussion with my referral source confirmed – that his pain behavior was considered to be primary evidence that his problems derived from something other than pain (see Prkachin 1992b; Prkachin & Craig 1994). This patient's experience was at the nexus of most of the theoretical and practical issues Williams' target article raises: What is the nature of pain signals? What are their primary determinants? What is their role in the communication of internal states and social regulation? What is their role in strategic presentation? How do others perceive them? Williams situates her analysis within evolutionary questions about the costs and benefits of both behavior and perception to the sufferer and the observer. She is to be commended for a treatment that is integrative, intellectually open, and clinically sensitive. I would like to take up a theme that I think is implicit in the target article, to highlight what I see as its overarching contribution, and to interject a *caveat*.

In his 1974 Nobel Memorial Prize address, the economist F. A. Hayek used the phrase "pretense of knowledge" to criticize the state of affairs in which public policy is driven by information and propositions that give the appearance of being scientific and precise in a manner in which they are not (Hayek 1975). Skinner (1974) was fond of using the term "explanatory fiction" in a similar way. In significant ways, the concept of pain behavior has provided the backbone of a knowledge-pretense that needs desperately to be corrected if theory and clinical practice are to advance. The concept of pain behavior as it has come to be used in the last two decades is monolithic, as I pointed out in a *Behavioral and Brain Sciences* commentary many years ago (Prkachin 1986). The model of pain behavior that has become ascendant clinically is based on a social learning approach (e.g., Fordyce 1976). It views the various forms in which pain may be expressed as largely arbitrary and governed by their consequences. In my view, it has served as a knowledge-pretense extraordinaire. Derived from the application of a theoretical lens to clinical examples of unknown representativeness, it has an apparent plausibility when used to interpret the behavior of people such as the man I described in the opening paragraph of this commentary. Perhaps the principal service that the target article performs is to emphasize that there are few (I would argue, there are no) unambiguously interpretable empirical tests of propositions of this model in representative, clinically relevant samples, whatever the model's plausibility and influence.

In contrast to such a monolithic perspective, the term "pain behavior" subsumes a variety of topographically different phenomena, including facial expression, that are arguably functionally distinct (Prkachin 1986). As Liebeskind and Paul (1977) also pointed out many years ago, there is every reason to believe that different pain behaviors are organized in different ways and at different levels of the nervous system. It is no less plausible to expect that they would have distinct evolutionary and developmental pathways and nonoverlapping roles in social regulation. The research on pain-related facial expression that Williams reviews has begun to establish the properties of this particular form of pain behavior. The adoption of a multidimensional and functional perspective should assist in mapping and articulating the nature and properties of other types of pain behavior. This will undoubtedly have the consequence of increasing the precision of our understanding of pain and pain behavior, giving us actual knowledge rather than pretense to work with.

The body of empirical work is consistent with interpretations of pain expression as the product of evolved propensities that shape distinct, communicative signals that play a role in social regulation, survival, and reproductive fitness. However, as Williams points out, virtually none of the empirical work that has been conducted on pain-related facial expression has been deeply informed by the concepts of evolutionary psychology. Instead, most has been driven by a desire to articulate the nature and properties of the signaling system of which pain expression is a part. The application of an evolutionary perspective may well add sophistication to our understanding of the organization and function of pain-related facial expression, and there is reason to believe that the same perspective may prove fruitful in the examination of other categories of pain behavior.

I am particularly struck with the importance of studying the question of cross-cultural differences and inter-species comparisons. But my caveat has to do with the risks of substituting one knowledge-pretense for another. In her closing section, Williams sets out an agenda of questions for future research: distinctions between acute and chronic states, relation to the multidimensional features of pain experience, perception of pain by others, and so forth. Most of the elements of this agenda represent clear and eminently answerable empirical questions that, in my view, stand alone, and may or may not benefit from an evolutionary perspective. It is a shame that premature closure around the explanation of pain behaviors – the pretense of knowledge – has delayed the pursuit of these questions. It would compound that shame if premature closure around a different orthodoxy had a similar effect.

The feeling of pain and the emotion of distress

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Abstract: An ethological analysis suggests that effort and protection actions, which are expressions of distress, are comparable with pain expressions. Distress occurs with uncontrollable pain, and the expressions are ritualized pain responses with exaggerated features and lower thresholds. Pain is a sensory-motor feeling state with aversive motivational (hedonic) value. Distress is an emotional state of failure of pain responses to control the pain.

Williams claimed that she was unable to find a pain face or emotion in the literature. However, I have described facial expressions which represent pain and distress: for example, a pain/suffering face (Salzen 1981) or a distress/pain face (Salzen 1991). Either is essentially an "effort" or "protect" face, comparable with the "protective" basic mammalian defence and rejection face described by Andrew (1963). Tension in the facial flexor muscles gives contraction around the eyes, retraction of the lips, and clenched teeth due to the contracted jaw flexor muscles. This grimace is part of a general body flexor tension. Accompanying sympathetic arousal gives gasping, which, coupled with a tense larynx and glottis, produces screaming and crying (cf. Andrew 1963). The grimace is seen in a rhesus monkey or a chimpanzee crouching from attack by a dominant. A similar expression is seen in the startle reflex (Landis & Hunt 1939) and in moments of extreme effort, as in weight lifting. Crile (1916), in an early evolutionary adaptation treatment of human responses to injury and disease, noted that the faces of athletes in extreme effort were similar to expressions of anger, terror, and grief. Tension for effort is present in these expressions, which also share facial elements with pain (cf. Williams' Table 1 in the target article). In chronic pain signs of fatigue appear, flaccid muscles giving drooping facial features, often with signs of residual effort in the brows, described by Crile for athletes *in extremis.* This is the face of grief. Fatigue is the predominant feature of the sad face, along with elements of pain (target article, Table 1). Fatigue from chronic pain, or other effortful strivings, produces despair and sadness (Salzen 1981). Interestingly, earlier studies describing the pain/grief face (Allport 1924), and the distress/anguish face (Izard 1971; Tomkins & McCarter 1964), are comparable with Ekman's "sadness" emotion category.

However, pain and distress are different concepts, and the distinction can be defined as follows: Pain is a sensory-motor feeling state with aversive motivational (hedonic) value. Distress is an emotional state consequent upon the failure of pain responses to stop or control pain. This distinction follows from the Thwarted Action State Signalling (TASS) theory of emotion (Salzen 1991), which is based on the ethological analysis of vertebrate social displays by Morris (1956). This theory has shown that social displays are derived from incipient actions or intention movements of blocked or failing actions, that is in frustration and conflict (thwarting) states. Intention movements can be used to account for a range of human facial expressions (Fridlund 1994; Salzen 1981). In the case of pain, the full behaviour in the form of bodily efforts to remove or control the pain can directly elicit help from a social partner, but this social signalling effect is incidental to the purposeful performance of the behaviour (Morris 1956). However, where the behaviour is unsuccessful, prominent aspects of the incipient actions that elicit helping responses may become, through evolutionary selection, exaggerated and formalized (ritualized) into specific signaling displays. It is this type of display that constitutes emotional behaviour according to TASS theory (Salzen 1991, Table 4.)

Thus, pain behaviour is *the action-pattern of pain in response to the sensation of pain, and together they give the sensory-motor feeling of pain,* which is hedonic; that is, it has motivational valency. When this action-pattern is unsuccessful in stopping pain, for example, when there is tissue damage, the sustained response state represents a thwarted action-state with a *thwarted-action pattern of distress behaviour and an emotional experience of distress or anguish.* This makes clear the difference between the *feeling of pain* and the *emotion of distress.* In common parlance, one can feel pain but not get upset about it, given control of the stimulus. It is well established that control of the stimulus enables higher acceptable levels of pain. Such levels are in fact "distress thresholds," whereas "pain thresholds," *sensu strictu,* are the levels at which pain is distinguished from other sensations. Excessive levels of all sensory modalities can give distress responses along with specific actions directed to the site of the sensation, just as for pain.

Distress behaviour, then, is the thwarted movements and postures of pain. These may simply continue with rising intensity (perseverance), and unless mixed with elements of fear and anger reactions, will be difficult to distinguish from the pain responses (cf. clinical judgement of pain). If features of the pain responses have become modified or ritualized, then the distress behaviour will be distinctive. So, can the reflex responses to nociception be distinguished from the derived facial, and especially, from the vocal, expressive signals to uncontrollable nociception? In fact, the reflexive or innate body responses to pain are so obvious to the bystander that there seems little need for ritualization to take place in order to capture attention. Even the form of the distress face is little different from the pain face.

The distress scream and cry, however, may have developed as distance signals to attract absent or inattentive social partners. Distress calling becomes muted or absent when no response is obtained, and the reflex pain responses are resumed, representing a return to the initial effect of thwarting, that is, perseverance of response (cf. Morris 1956). However, for both facial actions and vocalizations, ritualization could involve threshold changes that increase the readiness and intensity of these expressions to give earlier and stronger signals than the "genuine" body responses (giving clinical judgement problems again). Operant conditioning and learning can also act on these thresholds giving anticipatory distress faces both to impending stimuli and to painful thoughts. Suppression or exaggeration of these expressions according to the individual's life experience and cultural differences, would arise in the same way. The various social influences on the pain behaviour that Williams describes can be understood in this way as being variations in the emotional distress signals, rather than in the reflexive pain responses.

In short, the ethological analysis of pain as a feeling, and of distress as an emotion, can encompass Williams' evolutionary analysis of pain. And, I believe, it illuminates the difference between pain behaviour and distress behaviour, and also the role of experience in modulating the latter.

The evolutionarily novel context of clinical caregiving and facial displays of pain

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Abstract: Evolutionary explanations of pain expression require modeling social adaptations in a context where the role of health professionals as potential caregivers, conflicts with their status as relative strangers. As signals of help elicitation or of alarm, facial pain displays and responses to displays, particularly in the upper face, are expected to conform to this evolutionarily novel clinical context.

Williams argues that the operant model of pain expression that characterizes clinical practice in many cases, is inaccurate, at best, in explaining patients' facial expression of pain. As Williams notes,

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the suggestion that in response to clinicians' skepticism, patients be trained to "express pain in ways which doctors and nurses currently recognize" (target article, sect. 6), is a clear indication that the field of facial expression of pain is in need of new perspectives in general (Keefe & Dunsmore 1992). The practical significance of the target article is clear. This article is also significant because it provides an avenue for concrete contribution of evolutionary approaches to real world problems. Increased attention to the meaning of the clinical context with regard to adaptive properties of facial expression and the characteristics of naturalistic pain displays are central evolutionary issues in pain expression research, which may ultimately improve assessment and treatment of pain.

The fact that most of the studies cited occur in medical settings, in the absence of evolutionarily relevant caregivers (relatives and long-term social group members), is a major shortcoming of current pain expression research. The adaptive functions of facial displays of pain are expected to differ depending on whether or not the observers are strangers, family, or social group members (Schmidt & Cohn 2001; Williams 2002). The author identifies health professionals as potential caregivers, and argues that release of suppressed pain expression by patients represents help-eliciting behavior. A strong alternative possibility is that the facial displays of pain produced in the clinical context are reduced, and represent a response typically given to strangers rather than to potentially sympathetic care providers, thus reducing caregivers' helpful responses.

The author correctly stresses the point that the facial expression of pain, even when suppressed or amplified, need not be conscious. The release of suppression hypothesis for expressing pain in the presence of potential caregivers works only if the health professionals are consciously or unconsciously considered potential caregivers by patients. There is likely a great deal of variation in the patient outlook represented in the studies cited. A possibility is that the genuine pain expressions displayed in clinical contexts represent relatively low intensity expression, or differ in some other important way, from those displayed to the family or social group. This may produce a mismatch between verbal self-reports (given consciously to someone perceived as a potential caregiver) and facial signals (given to the same person who is essentially a stranger). If this is the case, then health professionals may miss these subtle signals, while family members are attuned to the much more intense signals they receive. Naturally suppressed pain expression may be an indication of the fact that modern humans so often experience pain in the presence of strangers, including health professionals. The concept of health professional as stranger also applies to observers' reactions, as suggested by the fact that over time, perception of individual patients by medical personnel, such as more experienced versus less experienced nurses (Hamers et. al. 1996), changes from one of potential social cooperators to one of potential cheaters or competitors for limited resources (i.e., the amounts of medication that can be prescribed). Rather than losing sensitivity to the facial expression of pain through increased exposure (which does not seem to happen to family members), health professionals develop a more clinical attitude and experience a reduction in empathy with patients over time.

Another relevant possibility mentioned in the article is that pain displays behavior functions as alarm signals. The prototypical expression for acute pain may be some combination of fear and pain, because acute pain in another individual may signal not only a need for help, but also an immediate threat to nearby observers. Family members might well be expected to take notice of signals of a relative's alarm because that would have meant a potential threat to their own welfare in an evolutionary context. The same alarm given to a stranger, especially one that is currently producing the pain stimulus, would produce a very different response in the observer – in this case, a health professional. Responding to an alarm could heighten family members' attention to other pain cues, such as self-reports or other, nonverbal signals. In contrast, a stranger (health professional) would not have an adaptive reason to respond to such a signal. If facial expressions of pain have a dual role as alarm signals and as solicitations for help, as the author suggests, then they could be expected to display elements of both fear and pain prototypes. In cases of chronic pain, however, facial actions associated with fear may not be present, and could lead to different responses in observers.

The simulation of facial expressions requires more explanation than the existence of spontaneous (either learned or innate) facial expressions, given the strong pressures for cheater detection abilities in observers. The ability of healthy individuals to produce deliberately simulated pain expressions is intriguing, and more work on the credibility of these expressions is needed. The speed and intensity of the signal are likely to be important in this case; spontaneous pain facial expression disappears rapidly, whereas deceptive facial displays have a longer peak duration and higher intensity (Craig & Patrick 1985; Hill & Craig 2002). Like the Duchenne marker in smiling (visible movement of the skin around the eyes in a spontaneous, "felt" smile), the results from simulated and amplified pain displays also show a discrepancy in movements of the upper face, (Frank et al. 1993; Williams 2002). As observers, people attend to the "more honest" upper part of the face in pain displays, where there is less voluntary control, arguing against the evolutionary significance of simulated pain displays (Prkachin et al. 1983; Rinn 1991). These observations provide potential directions for further research on the evolution of facial displays of pain, and on the specific relevance of the upper face in clinical situations where accurate detection of pain may be difficult.

Unfortunately, most of the studies that investigate simulated or exaggerated pain expression have focused on individuals that are actually already in pain, further clouding this contrast, and supporting the author's suggestion that results discussed in the studies cannot be used to identify malingerers that suffer from little or no pain. The results of these studies are difficult to interpret in light of the evolutionary hypothesis proposed. More interesting in the long term, as the author notes, are the signals that appear naturally in different contexts, and observers' responses to them. In addition, full consideration of the ambiguous social role of the health professional – both stranger and potential caregiver – is necessary for understanding the facial display of pain in the clinical context.

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The meaning of facial expressions of pain lies in their use, not in their reference

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Abstract: As a product of natural selection, pain behavior must serve an adaptive function for the species beyond the accurate portrayal of the pain experience. Pain behavior does not simply refer to the pain experience, but promotes survival of the species in various and complex ways. This means that there is no purely respondent or operant pain behavior found in nature.

> *For how does the complaint 'I'm in pain' differ from the mere announcement? By its intent, of course. And possibly that will also come out in the tone.*
>
> *–Ludwig Wittgenstein*

By treating facial pain expressions as the product of natural selection, Williams has opened a host of interesting questions about the biological functions of pain behavior. Foremost among the questions raised is: What functions, besides accurate depiction of an internal state, do facial expressions of pain serve?

Williams challenges us to think of the capacity for pain behavior, as well as the capacity for pain itself, as being adaptive in the evolution of our species. This has the radical implication that pain behavior does not exist solely in order to accurately manifest pain. Pain behavior exists rather to promote the survival of the species in a number of ways, some quite complex and indirect. The adaptive value of pain behavior cannot be understood in terms of the individual organism alone, for the care of injured members of our species is too important to the survival of the species. Because it has evolved in this social context, pain behavior is essentially, and biologically, a social phenomenon.

Pain researchers favor experimental and acute pain because it is the easiest to study. But it is now well known that this research focus puts too much emphasis on the noxious stimulus, the sensory aspects of pain, the reflex aspects of pain behavior, and the isolation of the one experiencing pain. Williams insightfully opens the question of the evolutionary roots and adaptive value of pain behavior by pointing us beyond the biological individual. "The 'problem' to which the facial expression of pain is suggested as a solution is twofold, concerning benefits to the signaller and to the onlooker. In certain cases, these differ for immediate response to threat of pain or pain on injury and for the responses during the recovery phase" (target article, sect. 3). Focusing on the recovery phase allows Williams to highlight "benefit to allies who receive information about potential danger" (sect. 3), and to qualify the benefits of candid pain display to the one in pain. "Benefits to the signaller in pain are more varied and uncertain, and must be set against the resource costs of signalling and the possible risk of increasing vulnerability" (sect. 3).

The mixture of benefits and risks for pain behavior means that it may be adaptive for a species to adjust the intensity of its pain behavior.

> At least partial control for the individual in pain over the amplitude of his or her pain expression allows strategic use of the signal; the ability of the observer to make at least crude distinctions between degrees of pain, without any specific information being added, is also advantageous. (target article, sect. 3)

There is, therefore, evidence of a complex social-evolutionary context for pain and pain behavior long before we enter the complex world of human pain litigation and disability evaluations. (Sullivan 1999).

Pain behavior has evolved in the social context of the species for millennia before it has been enacted in the contemporary social context. Thus, pain behavior is always a part of a "form of life" for a species. In this "form of life," it is connected to many important activities to do with caregiving and care-solicitation; resource allocation and conservation; and charity and responsibility toward other members of one's species. One possible variant of pain behavior is faked or exaggerated pain behavior. Under the influence of a Cartesian theory of mind and medico-legal procedures around injuries and accidents, we have become obsessed with this particular variant. Like Descartes, we so want to rule out the possibility of dissimulation in pain behavior that we forget that it can only be sustained as the exception to the rule. As Williams explains, "humans are alert to social cheating . . . , so that in any stable group the simulation of pain would yield rapidly diminishing returns and the withdrawal of help" (sect. 3, last para.). Pain and pain behavior are temporarily detachable for certain specific social purposes.

If pain behavior has evolved as a social phenomenon, the *meaning* of pain behavior will derive from its *use* in that social context, and not simply from its *reference* to a private pain sensation. By placing pain behavior in an evolutionary context, Williams thus makes the same point that the philosopher Ludwig Wittgenstein made when discussing philosophy of language and mind. "For a large class of cases – though not for all – in which we employ the word *meaning*, it can be defined thus: the meaning of a word is its use in the language game" (Wittgenstein 1953). Pain has meaning within a language game and a way of life. Pain behavior does not function in a human evolutionary or social context solely or even primarily to picture a private pain sensation. In this sense, pain behavior cannot be said to be *caused by* the pain sensation. The idea of completely candid or purely respondent pain behavior driven entirely by nociception, is an illusion created by experimental pain research. (Sullivan 2001)

Williams criticizes Fordyce's operant model of pain behavior because it implies a "*tabula rasa* at birth," that is, no evolutionary shaping of pain behavior. If there is this *tabula rasa,* then social factors can only serve to distort completely candid or "purely respondent" pain behavior, such as we might see in experimental and perhaps acute pain studies. She hints that the evolutionary account offers a richer alternative:

> The type of cost-benefit analysis generated by an evolutionary approach applied to the behaviour of the person in pain, and of the person who observes him or her, will bring better understanding of how conditioning processes affect or do not affect unconditioned behaviours associated with pain. (target article, sect. 8, last para.)

But here I think Williams hesitates to make the bold conclusion her argument supports: Even "unconditioned" pain behaviors have social roots through the evolutionary process. Thus, there is no purely respondent pain behavior (apart from experimental pain). Because of its evolutionary history, the facial expression of pain is always biological *and* social. Like the rest of biology, pain research needs both molecular and evolutionary explanations.

Children's facial expressions of pain in the context of complex social interactions

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Abstract: In children experiencing pain, the study of the social context of facial expressions might help to evaluate evolutionary and conditioning hypotheses of behavioural development. Social motivations and influences may be complex, as seen in studies of children having their ears pierced, and in studies of everyday pain in children. A study of opposing predictions of the long-term effects of parental caregiving is suggested.

Williams cites evidence that facial expression of pain is enhanced in the presence of potential caregivers and suppressed in the presence of neutral observers or strangers. Perhaps paradoxically, children often report that injections are less distressing when a parent is present although their overt expression of pain is greater when a parent is present. Williams offers an evolutionary explanation of this phenomenon: "the presence of potential caregivers prompts the release of suppression of pain facial expression" (target article, sect. 7). In contrast, the operant explanation is that pain expression in the presence of caregivers is amplified because it has been rewarded in the past.

Williams points out that distinguishing between these two hypotheses is of considerable clinical importance. The implication of the operant hypothesis is that it would be beneficial to withdraw reinforcing attention that is contingent on expressions of distress, as such reinforcement only promotes dependency and discourages coping. The evolutionary hypothesis carries contrasting implications for training and preparation of parents to assist with their children's painful procedures. When the child's expressions of pain elicit sensitive and responsive caregiving, it supports the development of confidence and independent coping in the child. For example, a controlled intervention to increase mothers' rapid and sensitive responsiveness to irritable infants' crying resulted in their becoming more effective at self-soothing as they increased in age (Van Den Boom 1994).

In considering other evidence that might be adduced in favour of each of these two contrasting positions, I remembered an illustrative incident. Of course, such anecdotal accounts carry no weight in hypothesis testing, but they sometimes point to possible studies.

Through a high window, I was able to unobtrusively observe my 6-year-old and 2-year-old daughters drawing lines on the driveway with chalk and running along the lines. They bumped into each other in what seemed to be a very minor collision, with neither one falling down. The 2-year-old continued playing, but the 6-year-old, in a bad mood perhaps due to hunger or fatigue, ran to the front door, a distance of about 20 meters, with an angry expression. She came in the door, and once she saw me, she started to cry ("release of suppression"), complaining that her little sister had hurt her shoulder. Her facial expression at this point seemed to show more pain than anger, though my own actions were predicated on my speculative interpretation that her intent was to get her sister in trouble ("exaggerated pain expression reinforced by its previous consequences").

If the reinforcement hypothesis is correct, then positive or solicitous attention paid to children's pain behaviour should increase it. On the other hand, if the evolutionary explanation is correct, then repeated elicitation of caregiving in situations of pain (or threat of pain) should lead eventually to greater security and independent coping in the child. Thus, the two accounts may lead to opposite predictions for children's later coping with pain where their parents provide positive consequences for pain behaviour early in life. A prospective study could examine later coping (e.g., with immunization injections at four to five years of age) in children whose parents are observed to reinforce, versus ignore, earlier pain behaviour. One might expect an interaction with age: Cuddling and reassurance for a hurt toddler would presumably have a different effect on later coping, than the same parental caregiving offered to an older child or adolescent whose current developmental task is separation from the parent and mastery of independent skills.

Williams suggests more study of "everyday painful events in humans and onlookers' responses to them, preferably covertly observed" (sect. 8). My research group had an opportunity to carry out such a study a few years ago (von Baeyer et al. 1998). We stationed observers in six day-care centers, during periods of active play among the 3- to 5-year-old children. An event-sampling instrument adapted from the Dalhousie Everyday Pain Scale (Fearon et al. 1996) was used to record observations of minor painful incidents such as collisions with other children, falls, and scrapes. We accumulated 112 hours of observation of 50 children, capturing a total of 51 minor painful events (and incidentally replicating the finding of Fearon et al. [1996], that children in this situation have minor "owies" or "booboos" at the rate of about 0.3 incidents per child per hour, though some children have a higher rate and others none).

Based on written descriptions of the events, we were able to score their apparent severity independently from judgments of the children's expressions of pain. The response of day care staff was also scored, from ignoring through verbal reassurance to picking up, cuddling, and first aid. The significant observation in the present context is that the intensity of the caretaking response by day care staff was unrelated to the severity of the incidents, but was strongly associated with the intensity of the child's expression of pain. In other words, a child who had a "severe" incident, but failed to express distress, got less attention than a child who had a minor event but expressed it with high intensity. We did not, however, adequately separate facial expression of pain from other pain behaviours, such as crying.

Ear piercing offers another opportunity for observation of pain in children without the complications of illness and fear of medical procedures (von Baeyer et al. 1997; Spafford et al. 2002). Children having their ears pierced, for the most part, have voluntarily sought it rather than having it imposed on them. Moreover, because the studs are shot into the earlobes by a spring-loaded gun, the physical stimulus is fairly standard, with minimal intersubject differences attributable to variations in operator skill or speed.

In the first study cited above, we videotaped children before, during, and after the ear piercing. Interestingly, in several children (perhaps a third of the sample), the classic differentiation of pain into first (sharp, rapid, epicritic) and second (dull, slow, protopathic) seemed to be observable in some children's facial expressions. The first pain response, a rapid wince and eye closing occurring within 0.2 seconds after the insertion of the stud, was probably mingled with a startle response to the loud click made by the ear-piercing gun. Commonly the child's face then relaxed into a smile or a neutral face for about 2 seconds (as if they were thinking, "That wasn't so bad"), and then a different, higher-intensity facial expression was displayed. This second pain expression had more in common with sadness: a frown, furrowed brow, and lateral mouth stretch, perhaps expressing the onset of a duller pain in the earlobe, a pain which in most children was more severe than expected (von Baeyer et al. 1997). Unfortunately, the prototypic pattern of facial expressions described above did not emerge as a group finding when formal facial action coding was carried out (Hale et al. 1998): It could be seen only in some participants, and then only with variations in time course and intensity.

The complex influences of social context on pain expression can also sometimes be seen in the ear-piercing situation. I have previously described the following interesting situation:

Identical twin girls, aged nine, are getting their ears pierced. Each watches the other's piercing, and the whole sequence is captured on the researcher's videotape. The first child conveys much distress in her pain ratings and her facial expressions, which, however, somehow appear posed; we see another hint of her having "hammed it up" or exaggerated her pain expression when she makes eye contact with her waiting sister and briefly grins. The second child, perhaps acting out an unspoken game with her twin, then displays a nonchalant air, indicating in her self-ratings and her face that the pain of ear piercing is inconsequential.

These twins, each given a pair of presumably nearly identical painful stimuli, behaved (nonverbally and in their pain ratings) very differently from each other. We have no direct evidence about the reasons for the differences, but we may surmise that social psychological characteristics of the measurement situation are much more important and influential than are nociceptive variables. (Champion et al. 1998, p. 148).

It appears that the evolutionary hypothesis might receive its strongest support from studies of early infancy and of strong pain, while the reinforcement hypothesis may best explain behaviour at later ages and with milder pain.

Williams' review will, I think, lead to much further discussion, theoretical elaboration, and empirical investigation concerning facial expressions of pain.

An evolutionary theory of pain must consider sex differences

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Abstract: According to Williams, human facially expressed pain, and its perception by conspecifics, is generated by evolved mechanisms. We argue that a key variable – sex (male, female) – needs to be considered for a complete theory of pain expression and perception. To illustrate, we cite findings on sex differences in pain and pain perception, and in crying and crying responsiveness.

Williams proposes that "human expression of pain in the presence or absence of caregivers, and the detection of pain by observers, arise from evolved propensities" (target article, Abstract). Her account is timely and important, linking a large body of evidence from the medical and psychological literatures on pain to modern evolutionary theory. This link has hitherto been neglected on both sides. However, the otherwise laudable target article is mute on sex (male, female) as a key explanatory variable in this context. Because sexual selection is a prime evolutionary force, and because human sex differences are pervasive, an evolutionary account seems incomplete when sex is not considered (Shackelford & Weekes-Shackelford 2000).

Sex differences in pain and pain perception. Sex differences in pain expression and pain detection are expected on the basis of sex-differentiated processes such as intrasexual competition, and, relatedly, status-striving and attempts at resource accumulation, among males on the one side, and heavier parental care and affiliativeness with children, kin, and family among females, on the other (Mealey 2000). Consequences of these sex-differentiated phenomena may include male attempts to hide facial expressions of pain, and poorer detection of pain in others; and female superiority of pain detection and more reliable expression of own pain.

Indeed, the literature on human pain and pain behavior is brimming with evidence of sex differences, which have been summarized in both narrative research syntheses (Fillingim 2000) and meta-analyses (Riley et al. 1998). There is also a recent *Behavioral and Brain Sciences* target article (Berkley 1997), documenting a vast array of sex differences in the pain domain. According to Berkley's deductive analysis, the three prime factors for sex differences in pain are sex differences in reproductive organs, in compositional features of sex hormones, and in temporal features of hormonal action. In females, for example, numerous pain-related conditions fluctuate with the menstrual cycle and, relative to males, enlarged variability in pain behaviors is to be expected in females.

The Williams article does not address either sex-differentiated evidence about pain-related expression and behavior, or Berkley's (1997) *BBS* target article. Sex as an explanatory variable is absent in the theorizing of the current target article. This constitutes an important omission. This is not to claim that there are noticeable sex differences in the *gestalt* or form of the facial expression of pain. We argue instead that it is also important to consider the perceiver's response to facially expressed pain, that is, to consider male versus female pain signaling in relation to male versus female responsiveness to signaled pain. Hadjistavropoulos et al. (1996), for example, demonstrated sex-differentiated pain perception by having observers judge videos and photographs of patients with back pain. The judgments covaried with patients' sex, as well as with their physical attractiveness: Male patients, relative to females, were judged to be functioning better, psychologically; likewise for physically attractive patients, relative to unattractive ones. These sex-linked and attractiveness-linked perceptual differences must be regarded as observer-biased, because they were not associated with actual patient functioning.

Sex differences in crying and crying responsiveness. Important sex differences also pertain to crying, weeping, and tearfulness. Crying can be regarded as a form of emotional coping behavior in response to psychological pain. It not only relieves tension, but also reliably elicits emotional support and therefore holds manipulative potential (Vingerhoets & Scheirs 2000). This behavioral category, not discussed in the target article, clearly is a form of both facial and acoustical expression of pain and is important in clinical contexts.

Sex differences in crying frequency and crying proneness have been demonstrated, the latter ones still evident when controlling for personality differences (Peter et al. 2001). Sex differences also extend to crying intensity, self-report of postcrying affect, and crying elicitors across interpersonal and stimulus situations (Lombardo et al. 1983; Williams & Morris 1996). There is also a sex difference in the median age of decline in childhood weeping (11 versus 16 years for males versus females, respectively [Williams 1982]).

There are not only sex differences in crying, but also in responsiveness to it. Examples include males showing a larger increase in skin conductance than females and further showing an increase in heart rate (unlike females) while viewing and listening to videotapes of a crying infant, whereas no sex differences in physiological reactivity emerge when a smiling infant is observed (Brewster et al. 1998). In another experiment (Condry et al. 1983), participants occupied with an unrelated task heard a nearby infant (girl versus boy) starting to cry. Females responded more quickly to the girl than to the boy, whereas males responded slower and without difference in regard to the crying infant's sex. A final example pertains to the mean fundamental frequency found for infant crying (Murry et al. 1977). Although mothers do reliably recognize their own crying infant from other crying infants, the sex of an unknown crying infant cannot be identified with reliability. There is a tendency for male infants to have a higher fundamental frequency in crying than female infants. This may confuse the listener and makes sense in the light of findings suggestive of sex-differentiated responsiveness according to sex-of-crier.

In all, there are important sex differences in the expression and perception of pain that add to the explanatory power, as well as to the clinical practice implications, of an evolutionary account of the facial expression of pain.

Author's Response

Facial expression of pain, empathy, evolution, and social learning

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Abstract: The experience of pain appears to be associated, from early infancy and across pain stimuli, with a consistent facial expression in humans. A social function is proposed for this: the communication of pain and the need for help to observers, to whom information about danger is of value, and who may provide help within a kin or cooperative relationship. Some commentators have asserted that the evidence is insufficient to account for the consistency of the face, as judged by technical means or in the perceptions of observers, or that facial expression is epiphenomenal to a gross behavioural defensive response to pain. The major criticism is that it is unnecessary to invoke evolutionary mechanisms beyond the emergence of an unconditioned facial response to pain in neonates, subsequently shaped and maintained by instrumental and social reinforcement throughout life. These criticisms are addressed, acknowledging the need for further data to address some, and elaborating the areas in which evolutionary and operant mechanisms would predict different behavioural interactions, rather than acting synergistically. Several supportive commentaries propose extending evolutionarily-based hypotheses to sex differences, the complexities of others' responses within the social relationship, and the role of empathy. A number of commentators provided valuable suggestions for experimental paradigms or methodological issues. Overall, addressing these issues indicates the need for further conceptual development and for collection of data specifically in relation to these hypotheses.

I aimed to raise issues concerning the role of evolution in the facial expression of pain and to invite reexamination of available data in the light of these issues: I am encouraged by the debate represented in these commentaries and particularly by the proposals for related empirical work. The criticisms and comments can be addressed in four sections. After a brief clarification concerning pain, I will discuss those which raise objections to the entire evolutionary thesis, on the basis of theory and of evidence (sect. R1); then those which acknowledge a limited role for evolution up to the production of an unconditioned response in the human neonate, after which behavioural mechanisms are held to be sufficient to account for behaviours of interest (sect. R2); those which endorse the evolutionary argument, find behavioural arguments insufficient, and take a more social-contextual approach to the behaviours surrounding expression of pain and the detection and response to that expression (sect. R3). The final section (R4) contains various directions and techniques to advance empirical work.

R1. Pain: What it is and isn't

First, the nature of pain needs clarification. I certainly did not intend to claim a multidimensional (including social) model of pain as the exclusive achievement of an evolutionary perspective (**Hermann & Flor**): the multidimensional model described briefly in the target article is propounded across theoretical divisions in the pain field. Pain is fundamental in a way that most commentators appreciated in terms of the universality among animals of response to noxious stimuli. Walters (1994) even hints that, in evolutionary terms, pain might be the forerunner of all negative emotions. In light of this model, it was difficult fully to answer those commentators who employ a simple model of pain: **Novak & Peláez**, **Harris & Alvarado**, and **Salzen**. The majority of commentators adopted the multidimensional model of pain, and even those such as **McGrath,** who are sceptical about evolutionary influences, are, as clinicians, aware of the extent to which doubts about and underestimation of pain occur and of the associated poor pain management as exemplified in the case described by **Prkachin**.

On the issue of the extent to which pain can be considered an emotion, **Izard** is right that I did not take a clear stand. This would have required far more consideration of theories of emotion than was possible in the main thesis, and would have been beyond the requirements of my argument, although it is fertile ground for discussion. I would agree with Izard that, compared to other basic emotions, pain expression involves very specific responses to a specific set of cues, and he presents a coherent conceptual framework to examine the relationship of pain and emotion expressions to various situations and cues. Both anger and sadness, which often accompany pain and become distinguishable in the second six months of life from the "all out emergency response" of infancy, are adaptive in their own right and elicit particular responses from caregivers (Huebner & Izard 1988). Izard's careful review of infant studies is very interesting, but the account of the failure of infants to learn to anticipate inoculation is inconsistent with other studies. Taddio et al. (1997; 2002) found that unmodified pain (circumcision without analgesia), or repeated pain experiences in neonates, predicted anticipation and enhanced behavioural pain response months later (see also Barr 1999).

Perhaps the best formulation at this stage is that of **Chapman & Nakamura** – widespread in the pain field and consistent with the neurophysiology of pain: that the experience of pain is partly emotion, and that responses of observers to pain will be to the emotional rather than the sensory aspects. This is not to say that further emotions, such as fear and anger (as described in infants by **Izard**), are not recruited on many occasions, but they do not fully encompass the emotional experience that defines pain.

R2. Rejecting the evolutionary contribution to pain experience

There is a general point to be made about the apparent counterposition of operant against evolutionary mechanisms. My objection is to the hegemony of operant explanations of pain-related behaviours, not to the thesis that aspects of those behaviours (such as the occasion or setting of their production, or their amplitude) could be influenced by learning. **Crombez & Eccleston** draw attention to the tendency in the pain field, which also emerged in several commentaries, for behaviourally-oriented writers to elide learning of display rules for the production of facial expression with the learning of facial expression itself. **Chapman & Nakamura** summarised it in their commentary: facial expression of pain was probably a reflex response to perception of tissue trauma, an instrumental behaviour, an expression of an emotion, and more.

There were three related strands among the commentaries that took a strong position against an evolutionary facial expression of pain: those which envisaged little or no role for evolution; those which found the evidence wanting for the pain face; and those which found the evidence wanting for detection of the pain face by others.

R2.1. No role for evolution

None of the commentators who rejected the evolutionary perspective provides a strong argument against it; that is rather, they provide a strong argument for the explanatory range of the behavioural model, which I discuss in section 2. Nor does any commentator explicitly reject the work of Ekman and others on evolved facial expressions of emotions (cf. Ekman 1989; 1993), on which my thesis relies, so I assume that they all accept it. Some critics, although apparently rejecting the evolutionary perspective, nevertheless invoke our ancestral past to some extent: **Novak & Peláez** refer to "instincts," "reflexes," and to behaviour that is "a result of ontogenic and phylogenic histories" and "environmental contingencies which have worked, distally, in the history of the species"; **McGrath** and **Hermann & Flor**, without elaboration, refer to unconditioned responses. But notions of instincts, reflexes, and unconditioned responses lack explanatory power without some suggestion of how they arose. In a fascinating application of selection theory to operant processes, Hull et al. (2001) describe all and yet no behaviour as the result of natural selection, in the sense that evolved behavioural variants are the essential raw material for other processes, including operant learning, to work upon. Their description is exemplified by the need of commentators to refer to some process by which behaviours emerged from randomness with nevertheless sufficient variety that, in interaction with environmental contingencies, they provided both successful and unsuccessful sets of behaviours. In a similar vein, **Sullivan** emphasizes that even unconditioned pain behaviours have social roots in their evolution, so that, outside the experimental situation, no pain can be regarded as purely respondent.

McGrath is concerned about the lack of fossil or morphological evidence. He is right that behaviour leaves little direct evidence, yet does not comment on the inferential evidence, mentioned in the target article, of serious yet healed injury as a demonstration that our ancestors understood others' suffering in some sense and provided vital help. As regards morphological evidence of facial expression, it is of little use to look for it in species whose social interactions rely less on visual channels than do humans'. Evidence of primate social intelligence and empathy is widespread (e.g., Byrne 1995; Preston & de Waal 2002), but primate observation of nonvocal communication offers us nothing on pain: we can draw no firm conclusions from its absence. McGrath also raises Gould's (1997) spandrel analogy without indicating of what adaptations in pain response the facial expression might be a spandrel of, or exaptation. Although the functions of pain behaviour would have evolved, as **Craig & Badali** note, the notion of spandrel or exaptation is of a characteristic without function, now or at any time in its evolutionary past; the shortcomings of Gould's position on this are well addressed by Alcock (2000) and Tooby (1999). The evolutionary psychology on which I drew is recognised as avoiding the circularity of some sociobiology, the original target of Gould's attacks, by a more focussed description of the advantages of likely adaptations (Thompson 2001). Tooby (1999) counters the criticism of adaptation as being nonempirical and unfalsifiable with a single criterion: that an adaptation solves an ancestrally recurrent problem at a better level than random coincidence of structure or behaviour with function; or, put as a question, would it be harmful if the behaviour were abolished or replaced by random behaviour? Stated like this, random or general negative facial expression would have the disadvantages detailed in the target article, both for the person in pain and for those observing it.

R2.2. No pain face?

Pantic & Rothkrantz, **Salzen**, **Panksepp & Pasqualini**, and **Harris & Alvarado** are unconvinced of the specificity of the pain face. **Frijda**, Panksepp & Pasqualini, and Salzen suggest the same nonsocial explanation of facial expression: that it constitutes part of a whole body response to pain, an effort to withdraw from the stimulus and to protect the body. In Salzen's case this is based on an explicit "sensory-motor feeling state," which is "aversive," but distinct from secondary distress due to the continuation of pain despite the initial response. This suggestion is, however, at odds with the evidence of emotional processing as integral to pain experience (Chapman & Nakamura 1999; Price 1999). In fact, no such whole body behaviours have been described that are specific to pain in humans or in laboratory or domestic animals. Various behaviours are detailed in the literature on infant and child acute pain (including in studies reviewed in the target article), one of which is the apathetic or tense immobility frequently overlooked in children in pain. A whole body response would also need to provide proportionate benefit to the individual, to offset the considerable resource costs of a vigorous physical reaction to an injured and endangered individual; and this is hard to argue convincingly.

Further, given that the face is for other interactions such a rich source of information, and the primary target of visual attention between humans, some justification is required for collapsing facial activity into gross motor activity in relation to stimuli. **Prkachin** makes a strong point, borne out by empirical work, of the distinctness of various pain behaviours such as facial grimacing, touching and rubbing, guarded movement, and sounds. The proposal that facial activity is protective is also somewhat unconvincing, as **Craig & Badali** commented:

> Unlike limb and bodily movements, the facial display during pain can only minimally protect during injury, for example, narrowing or closing the eyes to protect them. Facial grimaces cannot eliminate or terminate the source of pain other than through eliciting the interventions of others and do not appear to serve homeostatic functions.

Two sets of commentators find the assertion of a specific pain face premature: **Pantic & Rothkrantz**, and **Harris & Alvarado**. The former take an empirical approach, which I welcome and which I hope to see repeated as data accumulates, particularly using real, not posed, expressions. Harris & Alvarado apparently reject, on what grounds it is not clear, data presented in the target paper (sect. 5, and Tables 1 and 2) on co-occurrence, incidence, relationship to pain stimuli, and differentiation from other facial expressions, which they feel is required. Puzzlingly, they then equate the various co-occurring facial action units of the pain face with a single one of the combination, lip corner stretch (AU12), and thereby equate pain expression with an appeasement smile. Such elision of different facial expressions on the basis of a shared FAU is mistaken and cannot serve to clarify their functions.

R2.3. No detection of pain face?

I would not disagree with **Hermann & Flor**'s contention that there are gaps and shortcomings in the evidence for detection of the pain face, not least because the evidence I reviewed in relation to the criteria specified did not arise from testing evolutionary hypotheses. However, sharing of AUs across expressions is not a problem for the hypothesis: Several negative facial expressions share FAUs but this does not, for instance, render observers unable to distinguish anger from fear or sadness (see Frank & Stennett 2001). Several studies reviewed in the target paper support the distinction of pain from other negative emotions by observers; and although this is not perfect, nor is intensity well conveyed, detection and interpretation only have to be effective, not perfect.

Underestimation of pain is quite distinct from failure to detect pain, and I believe the evidence I presented amounts to better than **Harris & Alvarado**'s summary that "people are poor at reliably detecting another's pain." More ecologically valid studies; dynamic rather than still photograph methodologies; and the inclusion of the pain face among faces investigated by emotion researchers will provide valuable data with which to address these hypotheses. Examples of this sort are: (1) the use of real time observation and classification by observers of pain behaviours in adults (Prkachin et al. 2002), which showed that grimacing (a compound of facial expressions) was one of the two behaviours that could reliably be assessed (the other was guarding); and (2) the maturation of sensitivity to pain in others' faces by children from 5 to 12 years (Deyo et al., in press). There is still no coherent theory guiding or drawing on observations of systematic underestimation. The possibility of systematic bias (of whatever provenance) in relation to social contingencies is worthy of investigation, as **Crombez & Eccleston** recommend.

I did not intend to suggest that adaptations of facial expression had arisen specifically in relation to clinical attention, a postulate addressed by **Evans** and by **Harris & Alvarado**. Medical caregiving, whether by trained experts or lay practitioners, forms only a small subset of interpersonal responses to pain and physical discomfort. Across social and medical contexts, I suggested that the function of the facial expression is to elicit social assistance of a helping kind, and my comments referred to general helpgiving, from maternal care to help given by a stranger. Such helpgiving would be dated not by medical practices (Evans gives the example of trepanning at least 7,000 years ago), but by the evidence of healed major fractures (200,000 to 100,000 years ago) mentioned in the target article – injuries that would have immobilised the individual, who would therefore have died without feeding and probably other care. Following a review of empathic behaviours in a range of animals, including studies where pain evokes an empathic response in an observing conspecific, Preston and de Waal (2002) find sufficient support for the thesis that "empathy is a phylogenetically continuous phenomenon," at least among group-living mammals. They raise the possible role of mirror neurons: Hutchison et al. (1999) showed that the same cell in the human anterior cingulate cortex responded both to painful stimuli and to observing the same stimulus applied to another. All these suggest a role for empathy and empathic behaviour that is far wider than that formalised in medical care.

A more immediate issue is whether an evolved (and nonconscious) cognitive strategy could play a part in underestimation of pain by clinicians (and by others whose resources might be exploited by the person in pain). Underestimation of pain is reformulated by **Harris & Alvarado** as a deliberate diagnostic strategy, although the actual effect of high suspicion is likely to be a high hit rate at the cost of a high false positive rate. In the case of a low base rate of the target (as is the case for deception: Craig et al. 1999), this constitutes a poor strategy, shown to undermine successful diagnosis and effective treatment (Cleeland & Ryan 1994). **McGrath** is sceptical about how an evolutionary perspective could reduce patient blaming: the connection is not direct, but at present we have no model with which to understand this behaviour, much less to counteract it. But if underestimation of pain is based on an evolved strategy rather than on beliefs about patients' motivation, and a nonconscious processing bias (such as cheater detection) is activated by the social relationship, then intervention by information and education (so far, not a very effective intervention: Craig et al. 1999) is unlikely to be effective.

R3. Behavioural explanations and their application

McGrath, **Hermann & Flor**, **Novak & Peláez**, and **Panskepp & Pasqualini** argue that social learning or operant mechanisms are sufficient to account for regularities in pain facial expression; **Crombez & Eccleston**, **Chapman & Nakamura**, **Craig & Badali**, **Sullivan**, **Green**, **Schmidt**, and **von Baeyer** endorse parts or the main substance of my thesis. Further, **Crombez & Eccleston** and **Prkachin** agree with my assessment of the unsatisfactory state of evidence for widespread application of the operant model to pain-related behaviour; I value their directing attention to neglected classical conditioning mechanisms, and to the topology of behaviours classified as pain behaviours within the overall motivational system, as issues that should be incorporated into developing alternative accounts of pain behaviours.

The position presented by **Hermann & Flor** appears to pivot on a radical behaviourist view of pain, which is that once healing is complete, pain behaviour and expression is necessarily dysfunctional. This is problematic for two reasons. One consists of the pain phenomena which arise from plastic changes in the peripheral and central nervous system, and which do not remit with tissue repair. Given that Flor has carried out important work in cortical plasticity, her position is bewildering although true to Fordycean propositions (Fordyce 1976). Second, this view appears to equate the function of a behaviour with its consequences, part of operant reasoning (perhaps its own version of "Just-So Stories") but is inappropriately applied to evolutionary mechanisms, which cannot anticipate longer-term, nonlethal disadvantages of defences against immediate life-threatening events (Nesse & Williams 1994). It is not an argument against adaptations that they may have some disadvantages for the organism, as long as they are convincingly outweighed by advantages that were influential in selection mechanisms (including sexual selection). **Keogh & Holdcroft**'s suggestion of stoicism as a signal of male fitness is of interest here. The evolutionary theorist is concerned with whether pain expression consistently elicits care from kin and nonantagonist others, with limitations imposed by the immediate costs and benefits on each side, and with the possibility that repeated interactions might instigate the use of different strategies from the single encounter. The long-term consequences of certain pain behaviours – including those which are socially mediated, such as personal care – may well be disabling; although, as described below, I believe the situation is more complex than that suggests. Learning, on both sides, is clearly important, yet I would emphasize that it is not context-less learning: the potential danger to the individual and to those around him or her, represented by whatever caused pain to him or her, may be of crucial importance. The broader context, also an essential part of the picture, involves altruism, helpgiving within a family or social group, empathy and social intelligence, and, as **Chapman & Nakamura** state, consciousness itself.

A less radical view sits alongside these: that the unconditioned (and evolved) behavioural responses to the distress of pain are "brought under operant control and will be shaped by it" (**Hermann & Flor**), which the latter commentators approximate to acquired display rules (this is within Ekman's model of expression of primary emotions). Hermann & Flor are right that "the evolutionary approach and the operant model do not necessarily contradict each other with regard to the presumed function of pain expressions to elicit help and care from the observer," and this is discussed in section 1.1, but the models conflict on labelling that behaviour as maladaptive. Flor's work is among the most convincing of the demonstrations of operant shaping of pain expression, but – with a handful of exceptions – the only expression of pain shown to be modified by contingencies is verbal expression, that is, the report or rating of pain elicited by the researcher. Generalisation from this to spontaneous behaviours in nonexperimental settings is unsafe. Few studies (an example is Romano et al. 1995) use spontaneous pain complaint, a more convincing dependent variable than elicited pain rating; fewer use nonverbal pain behaviour – though a study by Flor et al. (1995), which includes withdrawal from the painful stimulus (pain tolerance), does.

The need to distinguish between the various pain behaviours is a point strongly made by **Prkachin**. But where facial expression is mentioned it is combined with other behaviours for analysis (e.g., Romano et al. 1992). A recent exception is a study by Chambers et al. (2002), who found little support for operant control of pain expression in an attempted manipulation of pain responses of 8–12 year old children; only pain intensity report, and only in girls, changed in the predicted direction with maternal positive or negative response. The report of pain affect, facial expression, pain tolerance, and heart rate did not change with maternal response, and in boys, none of these variables was subject to operant control.

So, the available evidence tells us little about facial expression, and particularly, about influences in infancy and childhood. But how good is the evidence that other pain behaviours are operantly maintained in adults? On careful review (see Newton-John 1999) the situation is far from clear. Where operant predictions have been supported by empirical test, this is generally specific to particular values of such variables as sex (see Turk et al. 1992), type of pain, marital quality, mood, pain intensity (the latter two in Romano et al. 1995, on which **Hermann & Flor** put some weight), and the source of the judgement of spouse solicitousness. Further, spouses' solicitous comments, which in careful sequential analysis followed and appeared to reinforce pain behaviours on patients' parts, also preceded those behaviours (Romano et al. 1992), suggesting a more complex interrelationship than the operant formulation encompasses. Patients' perception of spouse behaviours (including those which provide help and are thereby seen as reinforcing disability) are better related to patients' function or lack of it, than is observed spouse behaviour (Flor et al. 1987b; Williamson et al. 1997). What is more, on questioning, some patients find "solicitous" behaviours of their spouses distressing, diminishing, and denying of their autonomy, rather than rewarding; a smaller number report "punishing" responses as encouraging (Newton-John 1999; Newton-John & Williams 2000; Turk et al. 1992), so the assumptions of reinforcement contingencies represented by observed behaviours, without the context of the relationship within which they occur, are unreliable.

Panksepp & Pasqualini and **Novak & Peláez** use examples of behaviour to argue similar points. Panksepp's example of the limping child could, of course, concern a child with or without pain who seeks to gain attention and sympathy. But only a simple sensory model of pain, and the assumption that pain is closely associated with the state of the injury, allows us to assume that the child has no pain or too little pain to justify the limp. By contrast, a multidimensional model of pain proposes that limping is multiply determined: not only by pain intensity, but by distress associated with pain or by fears about further pain or physical damage (Vlaeyen & Linton 2000). Similarly, **Novak & Peláez**'s example of the child seeking the parent's response before s/he cries (or not) after a fall, must consider shock and distress as well as pain; thus, the parent conveys information about severity of the experience (not just of pain), comfort for distress, and/or cues for coping (such as those often given verbally). And, as **Crombez & Eccleston** point out, care is not primarily analgesic, so the parent's response is intended more to resolve distress than to reduce pain intensity. The operant model suggests that a consistent parental or adult response of sympathy, reassurance, and comfort, risks later exploitation of limping for these ends, but there is little empirical evidence to be brought to bear on the question, and, to my knowledge, no longitudinal studies. Of interest is infants' learning self-soothing through prompt parental responses to their crying (Van Den Boom 1994, described by **von Baeyer**). As **Craig & Badali** state, since deceit and exploitation are possible, socialisation of pain expression aims to encourage self-management with conservative use of others' help. The more detailed example of Novak & Peláez, of the infant's learning from his or her mother's response whether or not to reach for an ambiguous stimulus, cannot demonstrate the development of infantile responses to pain, which is anything but ambiguous or trivial.

R4. Social communication: Pain facial expression and others' responses

Sullivan, **Chapman & Nakamura**, **Craig & Badali**, **Evans**, **Prkachin**, **Izard**, **Schmidt**, and **Green** develop ideas around the social dimension of evolved pain facial expression and the responses of observers. A social function of pain facial expression suggests an adaptive value, as **Sullivan** points out, for people other than the individual in pain. This contrasts with the silence of the operant model on why parents and others provide care, help, and sympathy to the child or adult in pain. Exposure to others' distress is aversive (Preston & de Waal 2002), and the operant model tends to neglect an account of the reinforcement contingencies that establish or maintain caring behaviours. In addition, in general the resources expended in care vary with biological relatedness, in humans and in other animals, in a way that has not been shown to map onto apparent reinforcement contingencies. In relation to observers' responses to pain facial expression, **Chapman** invokes fundamental questions of "why empathy exists, the adaptive importance of empathy, and whether facial expression is a mechanism of empathy and second-person consciousness." **Crombez & Eccleston** point out that not only can an empathic response mitigate distress in the pain sufferer (as described by patients in Dar et al. 1992), but we must also address empathic distress in the observer, for which underestimation of another's pain may well be a management strategy.

Pain sufferers show concern for distress caused to close others, to the extent that they attempt to suppress behavioural signs of pain of which they are aware (Wilkie & Keefe 1991; Dar et al. 1992). I appreciate **Crombez & Eccleston**'s development of my suggestion that suppression of facial expression is released when the person in pain perceives the caregiver as sufficiently robust, and it suggests further questions to be asked in studies such as those they cite. This line of investigation will benefit from an explicit focus on the observer as more than a potential source of reinforcement; on the functions of empathy; and on other means of dealing with distress evoked by another's suffering.

A separate issue is voluntary amplification of pain facial expression, which **Green** interestingly reframes from dissimulation and/or attempted exploitation to a deliberate strategy to deliver a clear message of need. As he points out, the notion of authenticity of the signal is not heuristic. Green's proposal suggests an alternative interpretation of the possible outcome of comparing subjects' pain expressions when they believed themselves unobserved, to their expressions (assuming the pain to be the same) when they believed themselves to be observed by a friendly caregiver. Greater amplitude of expression in the latter case might support both the hypothesis of release of suppressed expression in the presence of a friendly caregiver and that of voluntary amplification to better solicit aid from a promising source, however honestly.

I am grateful to **Keogh & Holdcroft** and to **Voracek & Shackelford** for their elaborations of sex differences in pain expression and responses to it. While I appreciate the excellent work by Berkley (1997; see also the edited collection by Fillingim 2000), at the time of writing there were almost no relevant data in the studies I reviewed, and it seemed possible only to speculate about sex differences. However, Keogh & Holdcroft's suggestions about male signalling of fitness by control of facial expression of pain is consistent with evolutionary psychology theories about sex differences (Miller 1998), and their comments about female sensitivity to facial expression are consistent with available data from pain studies. Reanalysis of other pain studies may be warranted.

R5. Empirical possibilities

Several commentators agree and expand on the problems of currently available evidence and the frameworks within which it is gathered. **Chapman & Nakamura** are eloquent in promotion of the "second person position" (by contrast with first person subjective studies, or third person observation and judgement studies): that is, of "shared awareness grounded in empathy." They and **Craig & Badali** emphasise the extent to which the focus on the sensory experience of pain has excluded other dimensions of pain, such as distress, and has also excluded empathic and other responses to it. **Crombez & Eccleston** and Chapman & Nakamura argue for learning and other models, to use wider frameworks which incorporate social interactions; **Prkachin** calls for topographical and functional distinctions of the various behaviours related to pain. Despite **Harris & Alvarado**'s comments, I remain concerned about the extent to which the social dimensions of experimental studies – supposedly excluded by the paradigm – may still influence subjects' responses, particularly when they are asked to dissimulate, a major strand of pain expression and communication work. **Hermann & Flor** ask if observers could detect pain without contextual information suggesting pain (as in Frank & Stennett 2001); unfortunately, emotion theorists very rarely include pain in studies of facial expression. **Evans**' commentary raises some important points about the breadth of the social dimension of pain for the individual with pain and the observer-caregiver, and intriguing and original ideas on placebo responses.

Several commentators propose studies to distinguish evolutionary from operant mechanisms. For example, **von Baeyer** suggests that if expression of pain is greater in the presence of caregivers than among strangers or alone, then an operant theorist would recommend withdrawing attention to reduce dependence on others, whereas an evolutionary theorist would recommend empathic responses depending on age and resources, along the lines of the Van Den Boom (1994) study he cites. Related issues of ecological validity are raised by **Schmidt**, who recommends the use, in studies, of evolutionarily relevant caregivers – that is, kin and close others – rather than of stranger-caregivers, as in the medical setting. I would like to see replications of the studies so often cited to support operant learning of pain complaint (such as Block et al. 1980), in which facial expression of pain, and behaviours other than pain rating, are the dependent variables; and also, as **Crombez & Eccleston** recommend, judgement studies designed to test the hypothesis that "inaccuracies" in estimating another's pain may be due to systematic bias related to social contingencies.

On the technical side, **Davies & Hoffman**'s suggestions of empirical work using tracking of visual search and fixation, particularly of formal and informal caregivers, are intriguing and promising. These commentators emphasise the need to access nonconscious processing, including attention and processing biases towards certain sorts of information, and mediation by kinship or familiarity of the observer to the person expressing pain. These tracking methods would provide valuable data of relevance to several of the questions raised in the target article and in the commentaries. I am less convinced that the direct neural measures of the kind sought by **Panksepp & Pasqualini** will resolve issues, as they are no more a gold standard measure of the pain experience (as these commentators appear to imply) than any other measure; but, certainly, they would add a further perspective to the complex phenomenon of pain.

R6. Conclusion

I hope that my enthusiasm for an evolutionary perspective, in which I am much encouraged by several commentators, does not appear to aim to replace one "explanatory fiction" or "pretense of knowledge" by another, as **Prkachin** cautions. Establishing the origins of, and influences on, the facial expression of pain will not progress if we attempt to explain all by either evolutionary, or by operant mechanisms, exclusively. But at the levels of empirical and observational data, and everyday clinical and caring encounters, the assumption of universal applicability of operant learning lacks scientific rigour, and the theory is misused to support withdrawal of care from people who are suffering. Either of these warrants further attention to the data and to the current explanatory frameworks.

In sum, these commentaries, however critical, have helped to clarify, extend, and to modify my hypotheses; several have elaborated and integrated their social dimensions and implications; others have provided very valuable directions for empirical work. I hope that readers will take these further, within the study of emotional expression as much as the study of pain.

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Letters "a" and "r" appearing before authors' initials refer to target article and response, respectively.

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