REVIEW OF THE ARTICLE

BEHAVIOURAL ASSESSMENT OF PAIN IN 66 HORSES, WITH AND WITHOUT A BIT

W. R. COOK AND M. KIBLER

In this review, I will try to analyze the research article by W.R. Cook and M. Kibler and discuss its strengths, weaknesses, and overall presentation of the findings. To achieve this, I will try to scrutinize the methodology employed in the study to determine if it was robust and appropriate for addressing the research questions. I will also evaluate the data sources' reliability and assess any potential biases that may have influenced the results.

In the equestrian community, there has been an ongoing debate regarding the use of bits versus bitless bridles on horses. This debate stems from concerns about the potential pain and discomfort caused by bits and the perceived benefits of bitless options. Bitting is a common practice in horse riding, but there has been limited research on the potential pain inflicted on horses by bits. The article, *Behavioral Assessment of Pain in 66 Horses, with and without a Bit* Study, found that a majority of the horses exhibited an aversion to the bit, with at least 65 out of 66 horses showing signs of discomfort.

This article is an example of an epidemiological and a prospective study in which subjects are followed over time, and data about them is collected as their circumstances change. In this article, the circumstance is whether the horses are ridden with or without a bit. During this research, the horse cannot provide variable feedback since horses cannot provide verbal feedback. A human patient can report pain and the pain scale, but this is not possible with a horse. Thus, in this article, the researchers have arcticized the pain indicators while the horse is ridden bitted.

There are some points I would like to argue about the way the study was held. In my opinion, the methodology can be questioned in this research. First of all, the study doesn't mention a standardized check-up before the experiment. Were the teeth of the horses checked or had an exam by a horse dental care professional before the experiment? An ill-fitting bridle can rub the horse's cheekbones, and an ill-adjusted or fitted curb strap on a double bridle can cause a horse pain in his chin groove.[1] Were all the equipment of the horses appropriate? The horse's upper and lower jaw are in different widths and lengths. Although this does not have an impact on the actual bit choice, it is essential in determining the size of the bit.[2] Horses' mouth is too sensitive[3] thus the size of the bit is a factor for determining the pain caused by the bit. Was there a control mechanism to ensure the right size of bits were used by the riders? Can we indicate that the horse had no pain whatsoever going on before the experiment? In my opinion, the lack of this knowledge makes the study less robust.

Atakan Tepebaşı[4], the head coach and the owner of Ömerli Atlı Spor Kulübü (which is currently residing 60 showjumping and 2 dressage horses) stated that there is a direct relevance between rider level and the sensitivity of riders' hands that affects the force of the bit on the horse's mouth. He also stated there is a difference between using a pelham or a snaffle bit, and he opts for pelham for his experienced riders because he thinks Pelham is a very stiff bit and the rider should handle the rein with care. He stated that this might result in the horse's mouth stiffening and making the horse harder to get cues from the rider leading to some discomfort with the horse (Tepebaşı A., Personal Communication, June 21, 2023) In reference to all this, I think rider level might be another variable in this study.

The researcher has indicated the experiment was carried on different 66 (gender, aged, breed, discipline) horses. The researchers acknowledged that the study group was not homogenous, as it included horses of different genders, ages, breeds, and disciplines. Despite this lack of homogeneity, the researchers did not attempt to deceive or mislead

1 [Book] Esterson, Emily. (2019) *The Ultimate Book of Horse Bits*. New York, USA: Skyhorse Publishing, p.30-314
2 [Book] Esterson, Emily. (2019) *The Ultimate Book of Horse Bits*. New York, USA: Skyhorse Publishing, p.29
"Horses jaw do not have a muscle- meaning there is no protection from pressure between the jaw bones and the nerves. Consider the feeling of metal on bone; that's what your horse feels from the bit. The nerves are so close to the surface. Pressure is translated instantly from reign to brain. Additionally, the nerves residing in both upper hard on soft palates are relatively exposed, meaning that, they too, are highly sensitive to pressure and pain."
3 [Book] Esterson, Emily. (2019) *The Ultimate Book of Horse Bits*. New York, USA: Skyhorse Publishing, p.28-29
4 [Person] Atakan Tepebaşı (1985) is a renowned showjumper in Türkiye who competed up to 1.50cm at a Grandprix level. He is currently a horse trainer and a coach for the riders (FEI Level II)

their audience. Instead, they openly discussed the lack of standardization in their research paper's "limitations" section (p.558). Also, this section addressed the lack of standardization and potential data-gathering issues. Their data collection was a convenience sample, meaning they used readily available horses. In this case, the study group doesn't seem to be homogenous. The variables (age, height, discipline, breed, gender) are very different in this experiment. Furthermore, a list of behaviors (ethogram) includes visual behavioral manifestations. Out of the 69 'pain indices', a number is not related to pain. For example, 'slow learner' is not a behavioral manifestation. 'Hates the bit' is an interpretation, not a visual manifestation.

In Rebekah Strunks' thesis research; *Effects or Rider Experience Level on Horse Kinematics and Behaviour,* Strunks examines how riders with varying skill levels affect limb joint kinematics[5]. Strunks, in her conclusion, states that this was a small study group (her test was conducted by 8 horses and 8 riders), and had less controlled parameters- that this data can be improved by extending the study[6]. If we compare this research article to Strunk's thesis, this article had larger control parameters and a bigger study group making us access to more data. But in my opinion, the controlled variables in this study can be questioned/challenged.

The results of the research were clearly explained and presented within this article. From the research's downsides to its strongest point, all was included. The graphs and figures were used to show support for the research, and each time there was a different table & graph to support the data that was essential to this article- and it was drawn from the results of the research. It was in detail and easy to interpret. And I couldn't think of any additional graph that could be altered for this article, in my opinion, all the possibilities were drawn.

I have searched on this subject and found an article from one of the same authors, W.R. Cook[7]. The article is about an ethnological survey based on 605 written reports from horsemen who had switched from a bitted bridle to a new bitless bridle. This article, *Behavioral Assessment of Pain in 66 Horses, with and without a bit* is written 15 years after this research. The article has a similar graph to indicate the pain signs, but in terms of graphs, figures, and tables (data) I think this article is richer and has more data. In the article *Bit-induced pain: a cause of fear, flight, fight and facial neuralgia in the horse,* we are able to examine that a large subject group will definitely give more information, but I think, it may also increase the variables, and we don't see the indication of those "other" variables as this article has indicated.

The context of the study hypothesis refers to the background and circumstances in which the research question is being formulated. In my opinion, the abstract does not offer a sequenced outline of the reason for this study and for the methodology. There is no measurement of how equine welfare would/could increase, no reference to statistical testing, and no clear conclusion that leads back to the hypothesis which is not clearly stated.

5 [Thesis] Strunks, Rebekah. [December 2017] *Effects or Rider Experience Level on Horse Kinematics and Behaviour.* Clemson, USA: Clemson University, p.ii
6 [Thesis] Strunks, Rebekah. [December 2017] *Effects or Rider Experience Level on Horse Kinematics and Behaviour.* Clemson, USA: Clemson University, p.24
7 [Article] W. R. Cook. [January/February 2003] *Bit-induced pain: a cause of fear, flight, fight and facial neuralgia in the horse.* Pferdeheilkunde 19. Massachusetts, USA: School of Veterinary Medicine, Tufts University

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Original Article

Behavioural assessment of pain in 66 horses, with and without a bit

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Summary

Horses can be ridden with or without a bit. Comparing the behaviour of the same horse in different modes constituted a 'natural experiment'. Sixty-nine behaviours in 66 bitted horses were identified as induced by bit-related pain and recognised as forms of stereotypic behaviour. A prototype questionnaire for the ridden horse was based on 6 years of feedback from riders who had switched from a bitted to a bit-free bridle. From a template of 69 behavioural signs of pain derived from answers to the questionnaire, the number of pain signals shown by each horse, first when bitted and then bit-free, was counted and compared. After mostly multiple years of bit usage, the time horses had been bit-free ranged from 1 to 1095 days (median 35). The number of pain signals exhibited by each horse when bitted ranged from 5 to 51 (median 23); when bit-free from 0 to 16 (median 2). The number of pain signals for the total population when bitted was 1575 and bit-free 208; an 87% reduction. Percentage reduction of each of 69 pain signals when bit-free, ranged from 43 to 100 (median 87). The term 'bit lameness' was proposed to describe a syndrome of lameness caused by the bit. Bit pain had a negative effect on proprioception, i.e. balance, posture, coordination and movement. Only one horse showed no reduction in pain signals when bit-free. The welfare of 65 of 66 horses was enhanced by removing the bit; reducing negative emotions (pain) and increasing the potential to experience positive emotions (pleasure). Grading welfare on the Five Domains Model, it was judged that – when bitted – the population exhibited 'marked to severe welfare compromise and no enhancement' and – when bit-free – 'low welfare compromise and mid-level enhancement.' The bit-free data were consistent with the 'one-welfare' criteria of minimising risk and preventing avoidable suffering.

Introduction

Pain in animals is defined as an aversive sensation caused by actual or threatened tissue damage; a negative mental state. Pleasure is defined as fulfilment of a biological drive for comfort and safety; a positive mental state. Current animal welfare thinking (Mellor 2015a) refers to 'pleasure' as a 'positive affective experience' (**Table 1**). The term 'affect' describes emotion (feeling), either positive or negative. It encompasses 'motivation'; an animal's urge to move towards or away from a stimulus, i.e. stereotaxis.

Used since the Bronze Age, metal bits have been accepted as part of the furniture of horsemanship and not subjected to scrutiny until quite recently (Cook 1999). In a review of equine pain assessment, the absence of data on 'abnormal bit behaviour' [sic] was noted by Ashley *et al.* (2005). Since then, three studies have compared ridden horse behaviour, with and without a bit. First, two unschooled 2-year-old horses in a 10-day period of foundational training performed "at least as well, if not better" without bits as two matched horses in snaffle bridles (Quick and Warren-Smith 2009). Second, four mature horses, in their maiden bit-free test, exhibited statistically improved ridden behaviour (Cook and Mills 2009). In two concurrent four-minute tests, first bitted then bit-free, riders' scores increased from a mean of 37 ('fairly bad') to 64 ('satisfactory'). Finally, a study of 16 therapeutic riding horses showed significantly more negative behaviours when bitted and positive behaviours when bit-free (Carey *et al.* 2016).

Pain studies in animals have not generally included removal of the pain's source. The arrow of direction in assessing most management interventions (e.g. castration) is from painless to painful. In the current study, the direction was reversed. Bit usage is an elective and almost daily intervention during many horses' working lives. Assessment of its effect on welfare is overdue.

As bits have been standard equipment for millennia, they are widely assumed to be indispensable and ethically justified. This being so, an opinion by welfare researchers is cited ... "Most horses exhibit clear behavioural evidence of aversion to a bit in their mouths, varying from the bit being a mild irritant to very painful" (Mellor and Beausoleil 2017). The same authors observe that evidence of aversion is available to all who seek by comparing the open mouth, head tossing and restricted jaw angle of many bitted horses – clearly apparent on YouTube videos – with the absence of these behaviours in videos of wild horses and of domestic horses when ridden bit-free or bridleless. The need for a list of ridden horse behaviours to be developed was noted by Hall *et al.* (2013).

The study objective was to start answering six questions:

- What behaviours are caused by the bit?
- How prevalent are they?
- How many bit-induced behaviours might one horse exhibit?
- Are they reversible when the bit is removed?
- Is a horse's welfare improved by removal of the bit?
- Can a horse be controlled without a bit?

The null hypothesis was that removal of the bit would cause no behavioural change.

TABLE 1: Prevalence of 69 pain indices in 66 horses, when bitted and bit-free. The mean reduction when bit-free was 85% (range 43–100) with a median of 87%. Many of the bit-induced pain indices jeopardised the safety of both horse and rider

Order when bitted	PAIN INDICES	Number of horses affected BITTED	number of horses affected BIT-FREE	Reduction when bit-free (%)	Inferred likelihood of horse having POSITIVE AFFECTIVE EXPERIENCES e.g., pleasures of safety, confidence, comfort, compliance, enthusiasm, motivation following removal of the bit and cessation or easement of pain
1	Hates the bit	53	0	100	The relief, pleasure and comfort of being without pain
2	**FRIGHT:**	46	4	87	One of the five major categories of fear (the five 'F's), replaced by calmness, ease and comfort
3	Stiff-necked	45	7	84	Freedom of the head: Ability to balance; smoothness and fluidity in the 'way of going'
4	Lack of control	43	6	86	Horse/rider high accident hazard replaced by willing cooperation, harmony and partnership
5=	Resents bridling	41	3	93	Drops head eagerly into bridle; exhibits enthusiasm for work
5=	Above the bit	41	3	93	Able to select the physiologically most comfortable (optimally balanced) head position
6	Muzzle rubbing	40	9	77	Relief from the persistent irritation and distraction of facial neuralgia
7=	Head shaking	37	8	78	As above for 'muzzle rubbing' - the relief from nerve ache
7=	Unfocused	37	1	97	Focused; not distracted; 'listens' to and complies with rider's signals
8	**FLIGHT**	35	1	97	Contentment; energy conservation; no propensity to bolt, rush or run away
9=	**FIGHT**	34	2	94	Calm, quiet, cooperative and willingly offers compliance
9=	Pig-rooting	34	2	94	See 'fight' above: Does not grab the bit and snatch reins from rider's hands
10	Difficult to steer	33	8	76	Ability to balance; steers straight and turns comfortably (also see 'lack of control' above)
11=	Stiff or choppy stride	32	2	94	Enjoys the natural rhythm of motion (also see 'stiff-necked' above)
11=	Reluctant to rein-back	32	10	69	Return of normal agility; one of many signs of reduced 'bit lameness'
12	Tail swishing	31	1	97	Removal of discomfort; tail movement in synchrony with spinal movement
13=	Hair-trigger response to bit	29	0	100	Calm and confident as opposed to 'highly strung,' anxious and apprehensive
13=	Sneezing & snorting	29	13	55	Restoration of normal breathing pattern; reduction of nasal irritation (facial neuralgia)
14	Yawning	28	4	86	Absence of yawning suggestive of reduced need to ease/interrupt pain signals (see facial neuralgia above)
15	Slow learner	27	1	96	Return of ability to learn - a vital survival strategy (see unfocussed above)
15	Uncooperative	27	3	89	See 'fight' above
15	Heavy on the forehand	27	6	78	Unhampered ability to balance, return of normal agility, elimination of stress and pain
16	Fails to stand still	26	0	100	Return of species specific default behaviour of calmness and contentedness
17	Pulling on bit	26	0	100	No need to defend itself from the bit and become unbalanced in the process
18=	Grazing on the fly at exercise	25	11	56	Less need to 'interrupt' pain signals (see 'yawning' above)
18=	Inverted frame	25	5	80	No pain - no high head carriage - return of ability to balance
19=	Dislikes wind/rain/sunlight	24	10	58	Relief from trigeminal hypersensitivity
19=	Tilts head at exercise	24	5	79	Proper balance with no need to try and avoid bit pain
19=	Fails to maintain trot or canter	24	4	83	Engaged, lively, energised, exhibits vitality of fitness
20=	Difficult to mount	23	3	87	Reduced anxiety and apprehension
20=	Grabs the bit	23	0	100	No need for defensive behaviour at exercise
20=	Lacks courage	23	5	78	Confident, engaged and curious about its environment
21=	Napping	22	4	82	Reduction of fear; reduced pain increases comfort (see 'Freeze')
21=	Stumbling	22	7	68	Reduction of 'bit lameness' with unfettered proprioception enabling a horse to keep itself upright and safe
22=	**FREEZE**	21	4	81	Keen to explore. Relief from the 'frozen' state of a prey animal when attacked by a predator
22=	Resents unbridling	21	1	95	Optimism rather than pessimism (see 'hates the bit' above)

TABLE 1: Continued

Order when bitted	PAIN INDICES	Number of horses affected BITTED	number of horses affected BIT-FREE	Reduction when bit-free (%)	Inferred likelihood of horse having POSITIVE AFFECTIVE EXPERIENCES e.g., pleasures of safety, confidence, comfort, compliance, enthusiasm, motivation following removal of the bit and cessation or easement of pain
22=	Behind the bit	21	1	95	Adopts head position based on proprioceptive signals (see 'above the bit')
22=	Head shyness	21	12	43	Abatement of trigeminal hypersensitivity, hyperalgesia or neuralgia
22=	Salivates excessively	21	2	90	A relatively dry mouth betokens contentedness at exercise
23=	Bucking or bounding	20	3	85	Less pain, more comfort
23=	Lazy or dull	20	4	80	Engaged aliveness
23=	Heads for the stable	20	6	70	Relishes exercise, fulfils biological drive and need for movement
23=	Jigging	20	1	95	Walks quietly and contentedly
24=	Unfriendly in stable	18	2	89	Return of normal (social) behaviour
24=	Anxious eye	18	2	89	'Soft' (rounded) eye - an indicator of comfort
25=	Ear pinning at exercise	17	4	76	Non-aggression equates with the default social behaviour of the species
25=	Open mouth (gaping)	17	2	88	Closed mouth and sealed lips; oral vacuum restored; default condition for unobstructed airway at exercise
25=	Lolling tongue	17	0	100	Another return to physiological and behavioural norm
25=	Reluctant to change lead	17	5	71	Return of normal agility with correction of 'bit lameness'
26	Bites at tack or other horses	16	0	100	Reduced facial neuralgia enables disposition to move beyond neutral to a more positive emotional state
27	Scuffs hind hooves	15	7	53	Soundness of limb returns with correction of 'bit lameness'
28	Backing-up	14	1	93	See 'fails to stand still'
29	Multiple wrinkles around muzzle	13	2	85	Relaxation of tension with elimination of pain
30	Crossing the jaw	13	1	92	As above - return to 'normal' behaviour when on the move
31=	Evades capture in paddock	12	2	83	Accepts rider as a member of its 'herd' or 'band'
31=	Sweats excessively	12	1	92	No stress, less sweat
31=	Over bends	12	0	100	Proprioceptively and physiologically comfortable head position
31=	Tongue over bit	12	0	100	No need for defensive behaviour following removal of the bit, unobstructed breathing
31=	Interfering	12	4	67	Another aspect of 'bit lameness' corrected
32	Rears	11	2	82	Reductionof bit-escape behaviour
33=	Runs wild on bitted lunge	10	1	90	More comfortable
33=	Lower lip slapping	10	3	70	More comfortable
33=	Incoordination.	10	1	90	Unhampered proprioception corrects 'bit lameness'
34=	Eyes water	9	2	78	Reduction of corneal pain (facial neuralgia)
34=	Exercise triggers cough	9	2	78	Reduction of pharyngeal angina (trigeminal neuralgia) and/or inflammatory airway disease
34=	Back problems	9	2	78	Relief of 'bit-lameness'
35	Retracts tongue behind bit	7	0	100	Return of default tongue position at exercise, oral vacuum, soft palate stability, unobstructed airway
36	Drops food	6	0	100	Elimination of 'sore mouth' (mandibular gingivitis)
37	Reluctant to drink during 'endurance' test	4	0	100	Ability to create an oral vacuum and relief of 'sore mouth' prevents dehydration

Upper case letters mark the five major categories of fear-induced behaviour (the five 'F's) in the questionnaire; i.e. fright, flight, fight, freeze and facial (trigeminal) neuralgia. Pain indices specific to the bit are shaded grey.

Method

Study design

Owner/rider assessment of horse behaviour, with and without a bit; a longitudinal, retrospective, questionnaire-based study. The number of behavioural signs of pain in each of 66 horses when bitted was compared with the number of signs when bit-free.

Questionnaire

The questionnaire (**Supplementary Item 1**) was based on 6 years' feedback from 605 riders who had switched from a bitted to a bit-free bridle (Cook 2003). As recommended, questions were posed using vernacular terms (Wemelsfelder *et al.* 2001). At the end of an 8-page manual for a bit-free bridle, riders were informed that a questionnaire was available for documenting behavioural changes. The questionnaire was mailed on request or, more commonly, downloaded online. The 6-page questionnaire comprised signalment; 106 'yes/no' questions about horse behaviour and signs of disease; and 10 questions describing a rider's feelings about riding. It was completed twice; once when bitted and again when bit-free. From the answers, the change in prevalence of 69 behaviours, occurring in not less than 4 of 66 horses when bitted, was assessed (**Table 1**).

Population selection

Owner/riders volunteered their participation in the study. Each horse served as its own control, inasmuch as its behaviour was compared before and after removing the bit. Between 2002 and 2016, 96 questionnaires were received. Sixty-six were completed correctly; a 'usable' rate of 69%. The inclusion criterion was that for each of the 69 behaviours selected for analysis, a yes/no answer must have been entered for both bitted and bit-free periods.

Statistical analysis

A matched pairs *t*-test was used to determine if there was change in the number of pain signals (pain indices) when bit-free. An alpha level of 0.05 was set for significance.

Welfare assessment

A numerical grading of behaviour was eschewed in favour of the Five Domains Model (Mellor and Beausoleil 2015; Mellor 2017). Welfare compromise was graded on a five-tier scale from A (no compromise) to E (very severe compromise). Welfare enhancement was graded on a four-tier scale from zero (no enhancement) to +++ (high-level enhancement).

Results

The age of the population ranged from 3 to 24 years, with a mean of 10 years and a median of 8 (**Table 2**). Including half-breds, the breeds comprised Thoroughbreds (n = 21), Arabians (n = 11), Warmbloods (n = 7), Tennessee Walking Horses (n = 5), Appaloosas (n = 4), Clydesdales (n = 3) and others (n = 15). Gender distribution was male (n = 40; 39 geldings and one stallion) and female (n = 25). Categories by predominant use were dressage (n = 22), pleasure (n = 21), trail (n = 13), eventing (n = 5) and jumping (n = 5). All owners rode 'English' style. Twenty-eight horses had been bitted for five or more years. The time a horse had been bit-free before the second assessment ranged from 1 to 1095 days (median 35; mean 108). Questionnaires were returned from North America (n = 46), UK (n = 14), Australasia (n = 3), Austria (n = 1), France (n = 1) and Holland (n = 1).

Bits used were snaffles, Pelhams and double bridles. The bit-free bridle used throughout was a crossunder (Dr.Cook®)[1]

Results are displayed in **Tables 1–3** and **Figure 1**. Answers to the six questions are summarised as follows:

- All 69 behaviours were caused by the bit, as judged by their significant reduction in prevalence when the bit was removed. Excessive salivation was the only behaviour not caused solely by bit-induced pain, being also a reflex response to an oral foreign body.
- Bit-induced behaviours, as a group, were highly prevalent. The total number of pain signals for the population when bitted was 1575 and, when bit-free, 208; an 87% reduction. From 66 horses, the number of horses exhibiting each behaviour ranged from 53 (80% of the population) to 4 (6%) (**Table 1**).
- The median number of behaviours per horse when bitted was 23 (range 5–51); when bit-free 2 (range 0–16).
- Most bit-induced behaviours were eminently reversible and the change was statistically significant (**Table 2**). The matched pairs *t*-test gave a P-value of less than 0.005, supporting a causal link between the bit and pain-induced behaviour (**Table 3**).
- The welfare grade for the population when bitted was judged to be D/0 (marked to severe compromise and no enhancement) and, when bit-free B/++ (low compromise and mid-level enhancement).
- None of the riders experienced loss of control when bit-free, quite the opposite. In only one horse was control unchanged.

The null hypothesis was refuted: 65 out of 66 horses showed a change in behaviour following removal of the bit.

Discussion

The data support previous observations based on anecdotal evidence (Cook 2003).

Horses exhibit stereotaxis; a word derived from the Greek *stereo,* 'hard, solid'. This fundamental property of (even) primitive life forms, also known as thigmotaxis, is defined as 'the positive (or negative) response of a freely moving organism to cling to (or avoid) a solid object'. Indisputably, a bit is a 'solid' object. A horse is innately programmed to (try and) move away from (evade) the bit, i.e. to display negative stereotaxis. A definition for thigmotaxis (Greek: *thigmo,*'touch') emphasises the point – "the motion or orientation of an organism in response to a touch stimulus". When the touch is painful, stereotaxic stimuli are stronger. It follows that the equitation mantra requiring a horse to 'accept the bit' is misconceived. Expecting a horse to accept an oral foreign body is a biologically unrealistic expectation.

Mason (2006) proposed a definition of stereotypical behaviour based on three causal mechanisms, i.e. 'repetitive behaviours induced by frustration, repeated attempts to cope and/or CNS dysfunction'. The reversibility of 69 behaviours in 65 of the bitted horses indicates that 'CNS dysfunction' was not their cause but 'frustration' and 'attempts to cope' are mechanisms consistent with the data. In Mason's words again, stereotypical behaviours are generally 'responses of normal animals to abnormal environments'. In captive animals, they stem from 'a deficit in housing or husbandry, where a deficit means something that the animal would change if it could (e.g. a motivational deficit linked with frustration; a health deficit linked with nausea or pain; or a safety deficit causing fear)'.

Observational evidence constitutes the foundation for animal welfare assessment and this evidence – carefully observed – is objective, not subjective. "Contemporary animal welfare science understanding" accepts the need to "focus on subjective experiences, known as affects, which collectively contribute to an animal's overall welfare status" (Mellor 2017). Inferences based on such observational evidence derive credibility from the underlying affective neuroscience in a process that "involves cautiously exercising scientifically informed best judgement" (Mellor and Beausoleil 2017). Thus, it is asserted that improvements in behaviour following removal of the bit enable inferences to be made about the aversive experience of bit-induced pain. The improvements cannot be dismissed as 'merely subjective'.

Collectively, the behaviours were predominantly manifestations of pain experience, expressed by aberrant movements of the head, spine and limbs. They ranged from too little movement (e.g. stiffening, freezing) to too much

TABLE 2: Results for 66 horses switched from bit to bit-free, sorted on number of days bit-free. The number of pain indices when bit-free was significantly ($P<0.005$) reduced in 65 of the 66 horses

Case #	Age (yrs)	BREED	Gender	USE	# of pain indices bitted	Time bit-free (days)	% reduction in pain indices bit-free
39	4	TWH	G	Trail	7	1	86
24	5	Arab/TB	F	Dressage	23	1	100
15	6	TB	G	Pleasure	5	1	60
22	6	Arab	F	Trail	30	1	83
29	23	3/4 TB	G	Dressage/trail	22	1	100
3	8	WB	G	Dressage	16	4	62
7	9	TB	F	Equitation/jumper	39	5	53
32	5	Welsh	G	Trail/Pony Club	24	7	96
57	8	QH/App	G	Trail	24	7	96
9	12	WB	G	Dressage/eventing	6	7	100
44	19	Arab	F	Trail	32	7	84
35	6	TB	F	Pleasure/endurance	23	8	87
1	5	TB	G	Trail	34	14	100
10	7	TB/QH	F	Pleasure	17	14	35
51	7	cob	F	Trail	13	14	100
55	8	TB	G	Pleasure	24	14	96
50	4	App	G	Jumping/hunter trials	26	19	88
48	4	WB	F	Dressage	37	20	100
12	6	QH	G	Western pleasure	24	21	83
27	3	WB	F	Dressage/eventing	19	30	100
42	7	TB/Trotter	G	Pleasure	12	30	100
45	7	Arab/Pinto	G	Dressage/trail	39	30	100
60	9	Paint	G	Trail	23	30	57
26	10	Gaited	G	Pleasure	5	30	80
43	10	Arab/QH	F	Pleasure/dressage	42	30	98
64	12	Arab	G	Endurance	23	30	100
23	13	QH	G	Hunter	16	30	0
52	22	TB	G	Pleasure	23	30	78
5	?	TWH	?	Pleasure	21	30	76
56	?	Andalusian	G	Classical riding	27	30	67
40	6	TB	F	Pleasure	15	35	100
25	16	App	F	Pleasure/trail	27	35	100
47	11	Morgan/WB	F	Dressage	29	40	100
49	12	cob	G	Jumping, dressage	21	42	90
13	14	TB	G	Dressage/pleasure	23	42	33
59	3	Draft/X	F	School horse	7	60	71
58	6	Draft	F	Trail	21	60	62
4	8	TWH	G	Trail	11	60	100
53	8	TB	G	Dressage/jumper	42	60	100
16	15	App	G	Dressage	43	60	93
31	?	TB	F	Dressage/trail	13	60	54
8	4	TB	G	Dressage/eventing	34	64	97
11	11	SDB	G	Pleasure/trail	24	64	77
2	11	Arab	G	Dressage/trail	31	72	94
28	5	TB	F	Dressage/eventing	10	90	70
18	7	WB	F	Dressage	29	90	100
17	8	WB	G	Dressage	29	90	100
19	9	WB	G	Dressage	27	90	100
62	11	Draft	G	Mounted patrol	9	90	35
63	18	WB	F	Dressage/jumping	34	90	97
34	8	TB/Paint	G	Eventing/pleasure	23	120	74
46	8	Arab	F	Pleasure/endurance	28	120	100
54	11	TB	G	Trail/ dressage	23	120	69
41	14	Saddlebred	G	Dressage/jumping	42	150	90
20	12	Arab/Pinto	G	Trail	18	180	83
65	14	TWH	M	Dressage/pleasure	28	180	89
6	22	Arab	F	Trail	12	180	83
61	3	Draft	G	Mounted patrol	17	240	87
14	13	TB/WB	F	Dressage/eventing	9	240	100
37	6	TB (OTTB)	F	Dressage	32	300	75
30	11	WB	G	Pleasure/trail	7	300	86
38	24	Arab/Welsh	G	Eventing/trail	43	330	93

TABLE 2: Continued

Case #	Age (yrs)	BREED	Gender	USE	# of pain indices bitted	Time bit-free (days)	% reduction in pain indices bit-free
21	10	Arab	G	Dressage/pleasure	21	365	67
36	10	TB/Conn	F	Dressage/eventing	51	720	85
33	8	TB/Paint	G	Dressage/jumping/trail	42	730	93
	23	TWH	F	Trail	24	1095	100

App = Appaloosa; Conn = Connemara; QH = Quarter Horse; STB = Standardbred; TWH = Tennessee Walking Horse; TB = Thoroughbred; WB = Warmblood.

TABLE 3: Results of the matched pairs *t*-test for means

	Bitted	Bitless
Mean	23.86	3.15
Standard deviation	10.88	3.99
Observations	66	66
Actual mean difference	20.71	
Hypothesised mean difference	0	
Degrees of freedom	65	
t Stat	14.50144	
Two-tailed P-value	4.75E-22	
t critical two-tail	1.997138	

The test was significant (P<0.005).

movement (e.g. bucking, bolting). That some horses may exhibit a few aversions to the bit is widely acknowledged. That every horse is programmed to be averse to the bit and that aversions are numerous is not. The current study showed that at least 65 of 66 horses exhibited aversion to the bit and that horses have not less than 69 ways of exhibiting frustration, attempts to cope and efforts to avoid bit contact. In a review of poor performance, 48 (72%) of these same behaviours were recognisable among 67 behavioural signs of pain compiled by Dyson (2016). Clearly, even though both lists are incomplete, the mandible and tongue (a sense organ in its own right) figure prominently as the seat of musculoskeletal manifestations of pain experience in the bitted horse. To this must be added pain from the lips, a particularly sensitive area of another sense organ – skin.

A bit stimulates nociceptors mediated by the trigeminal nerve in lips, tongue, teeth and bone. Gingiva is periosteum, the most sensitive part of bone. A principle of saddle-fitting is that saddles should not press on bone. A bit breaches this principle. In the male horse, the peridontium of the canine tooth roots lies immediately ventral to the dorsal edge of the so-called 'interdental' space. In the female, unerupted, vestigial canine teeth are common (Sisson and Grossman 1938). In both sexes, 'wolf' teeth (erupted and unerupted) may be present in this space. In cross-section, bits are circular and make point contact with the 'knife edge' of bone at the 'bars'. This can be assumed to cause a horse pain, just as it causes us pain if we press the barrel of a pencil sideways into our gums. When the edges of the tongue are pinched between bit and bone, this too is likely to be painful. Pain is also likely when lips are stretched longitudinally to twice their normal length by the bit's retractor effect. Finally, cuts at the commissures will cause pain.

In common with other mammals, the vestibular labyrinths and receptors in skin, muscle, tendon and temperomandibular joints of the horse's head mediate perception of orientation and motion in three planes; i.e. proprioception. Head proprioception controls not only movement and posture of the head but also dominates that of the trunk and limbs (Sherrington 1907). In the ridden horse, imbalance can result in a fall with potentially fatal consequences. Head proprioception constitutes a central balancing mechanism and is key to a horse's agility and athleticism. Painful restraint of the head by a bitted rein interferes with a horse's ability to balance. As a horse's head movement is synchronised with limb movement for energy economy in the work of breathing and locomotion, proprioception unfettered by nociception is crucial. A bit also obstructs breathing and probably triggers the negative affective experiences of breathlessness, i.e. respiratory effort, air hunger and chest tightness (Mellor and Beausoleil 2017). These unpleasant physical and emotional consequences of bit pain are also antithetical to athleticism. Thus, the bit represents an impediment to welfare, safety and performance. Noxious stimuli from the bit are proposed to be incompatible with the unimpeded function of at least four systems critical to performance: the nervous, musculoskeletal, proprioceptive and respiratory systems.

Dyson *et al.* (2018) observe that, since 2013 "there is an increasing awareness that horses can exhibit lameness when ridden, while appearing sound when trotted in hand". In common usage, the word 'lame' denotes a gait abnormality caused by pain in a limb. Another sense of the word is not limited to limbs and carries the wider meaning of 'disabled, imperfect and lacking in smoothness' (Webster). In this sense, at least 65 of the 66 horses when bitted were shown to be 'disabled'. When trotted-up in a halter, they were not limb-lame, but when bitted and ridden they developed an abundance of gait abnormalities. The term 'bit lame' is proposed to describe a syndrome of bit-induced disability, i.e. the 69 pain indices here studied. As bit usage is the norm in 'English' equitation and still frequent in 'Western' equitation, it seems likely that bit lameness will be found to be common in the ridden horse.

A provisional diagnosis of 'bit lameness' is testable. If, by removing the bit, a gait abnormality is corrected this confirms a diagnosis of bit lameness and differentiates it from primary limb and thoraco-lumbar-sacral lameness or the incoordination of equine protozoal myeloencephalitis (EPM). As the definitive diagnosis of EPM and other subtle gait abnormalities can be difficult, removal of the bit is recommended as an early step in the differential diagnosis of lameness and the evaluation of poor performance. Such a step is especially indicated to help interpret the findings of computerised gait analysis, a diagnostic methodology that has introduced a dilemma over defining the term 'lameness' (Van Weeren *et al.* 2017).

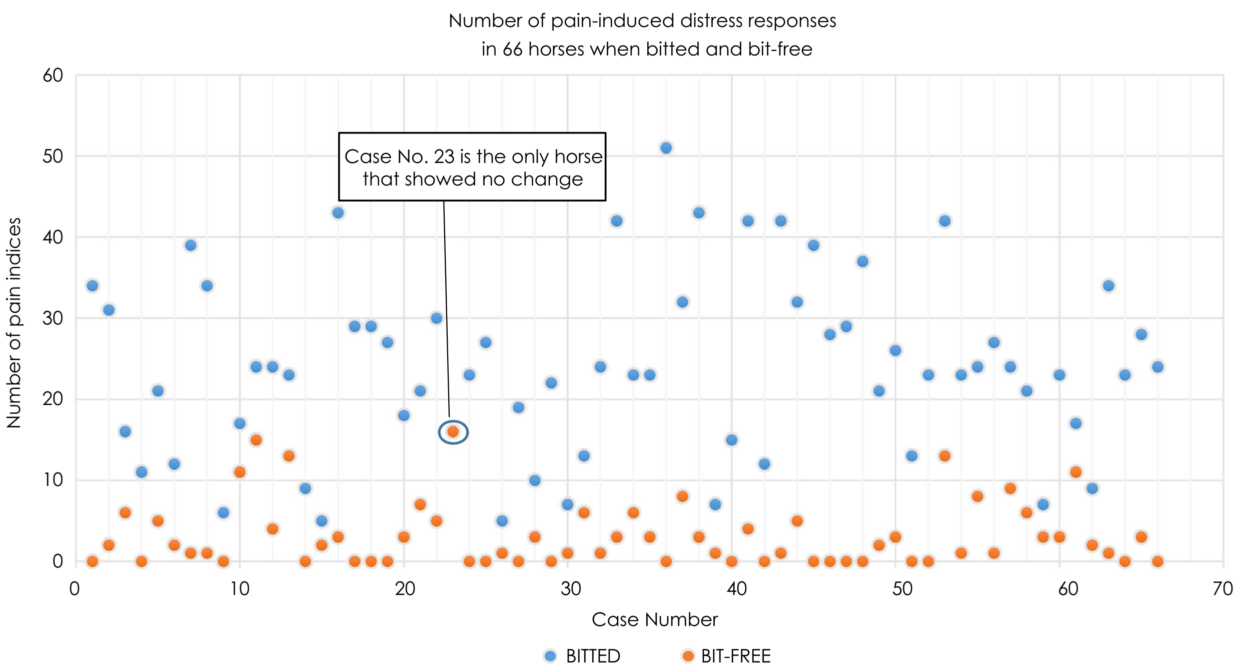

***Fig 1:** Individual value plot of pain index numbers in 66 horses when bitted and bit-free. When bitted, all 66 horses (100%) exhibited pain, with a range of indices from 5 to 51 (median 23). When bit-free, for a median time of 35 days, 66% still exhibited some pain but the range of indices was from zero to 16 (median 2).*

After owning a horse for years, riders discovered that many 'unwanted' behaviours they had assumed to be immutable character traits were corrected by removing the bit. They were sometimes aware that their horse was exhibiting signs of pain but, until they removed the bit, did not recognise the source. Often, the signs themselves were not even noticed until, following bit removal, they disappeared. Norm theory explains how signs of bit lameness, being so familiar, fail to elicit surprise and are assumed to be 'normal'. What ultimately did surprise owners was the unexpectedly large number of pain indices each discovered. It follows that riders need to carry out a bit-free test before asserting that their horse shows no sign of bit pain.

The most prevalent pain index was 'hates the bit', a family of behaviours shown by 53 horses (80% of the population) (**Table 1**). The full line in the questionnaire read, "Hates the bit, chomping, chewing or clenching the bit, grinding the teeth (bruxism), constant fussing with the bit, 'busy mouth,' evading contact" (**Supplementary Item 1**).

The second most prevalent index was 'fright', shown by 46 horses (70% of the population). In the questionnaire, the line read "Fright: Anxious, unpredictable, 'hot,' nervous, painful, shy, spooky, panicky, tense, stressed". It seems reasonable to assume that at least a quarter of the 69 pain indices imperil the safety of horse and rider (**Table 1**). The data support the opinion that bit-induced fear is the cause of many horse-related accidents (Jahiel 2014). Removal of the bit in 65 horses appeared to 'minimise risk and prevent avoidable suffering,' in accord with the concept of 'one-welfare' (Campbell 2013; Pinillos *et al.* 2016). In the feral horse, pain or the anticipation of pain (fear) is adaptive and promotes survival. In the ridden horse, pain is inimical to performance. A bolting horse can be in such fear and panic that it behaves as though blind and can run straight into standing objects. Case No. 36, with 51 pain indices when bitted, was described as dangerous to ride (**Table 2**, **Fig 1**).

A 'stiff neck' was the third most prevalent behaviour and shown by 45 horses (68% of the population). Its 84% reduction when bit-free is important for reasons over and above the relief of pain. Bitted-rein tension restricts movement of the head and neck, handicapping a horse's ability to breathe, stride and balance. Bedouin horsemen apparently understood this long ago. When their very lives depended on their horse's peak performance, Bedouins rode bit-free (Hanson and Cook 2015). Over half of the 69 pain indices when bitted were expressed by abnormal positions of the head and neck at exercise. Unfettered movement of the head-and-neck pendulum is a vital locomotory mechanism. Freedom of the neck is key to freedom of gait. Except when ridden by a master horseman (someone who rides with a loose rein and does not apply rein tension) a bitted horse can be unbalanced by rein tension and is likely to stumble.

The fourth most prevalent sign of pain when bitted was 'lack of control' (65% of the population). Its reduction by 86% when bit-free questions the rationale of competition rules which mandate bit usage on the grounds that bits control horses.

Twelve horses were assessed for the second time after having been bit-free for 14 days or less. Five riders completed the second assessment on day one (**Table 2**). Because of this and the persistent nature of neuropathic pain compared with nociceptive pain, the number of horses documented as having recovered from facial (trigeminal) neuralgia may not reflect the population's full potential for recovery from what was listed in the questionnaire as 'Facial neuralgia (the headshaking syndrome)'. The percentage reduction in the prevalence of this syndrome in the population was the lowest of the five major categories of fear (**Supplementary Item 2**). Yet the reduction was still encouraging compared with results from other treatments for headshaking (Mills *et al.* 2002). The 'headshaking syndrome' line item was checked for 37 of the 66 horses when bitted; eight when bit-free – a 78% reduction (**Table 1**). The word 'bit' derives from the word 'bite.' Clearly, bits bite. It is considered no coincidence that the headshaking syndrome includes many of the same behaviours caused by biting flies.

Space does not permit a paragraph on every one of 69 pain indices but the 'positive affective experiences' column of **Table 1** provides a précis.

Cognitive bias was recognised in the population. Mellor (2015c) describes the bias as follows – "negative emotional states may be accompanied by greater attention to threatening stimuli and more pessimistic interpretations of ambiguous information, whereas positive states may be accompanied by more optimistic judgments". The behavioural changes matched such a description; for example, the greater frequency with which bitted horses shied and spooked compared with their calmness when bit-free (see 'Fright' **Table 1**).

The 69 pain indices assessed in this study represent only a fraction of possible bit aversions. If, for example, a study was done on racehorses, it is predicted that many more bit-induced, pain-related indices (diseases and disabilities) would be identified. From a performance perspective, the most critical years in the working life of a Thoroughbred racehorse are those between the ages of one and four. These are the years in which canine teeth are developing in the interdental space. Bit-induced mandibular periostitis ('sore mouth') is the aetiological equivalent of metacarpal periostitis ('sore shins'). Both sides of the mouth are traumatised on a daily basis. The mouth is even more sensitive than the shin. Bit pain can trigger a cascade of locomotor and respiratory consequences; separation of the jaws – open lips – loss of the intraoral vacuum – instability of the soft palate – asphyxia – followed by fatigue, sprains, dislocations, fractures and falls – and/or negative pressure pulmonary oedema ('bleeding') and sudden death (Cook 2002, 2014, 2016; Mellor and Beausoleil 2017).

A horse learns to defend itself from the bit by gripping it between the premolars ('grabbing the bit'); trapping it under the tongue ('tongue over bit'); or placing it against the rostral edge of the first mandibular cheek teeth. Horses that try to disarm the bit in these ways are unfairly blamed for being 'hard-mouthed' or 'pullers'. The strategies result in bone spur development at the interdental space and/or dental erosion. Both defects are highly prevalent (Van Lancker *et al.* 2007; Cook 2011; Mata *et al.* 2015).

Ödberg and Bouissou (1999) reported that many horses are slaughtered at a young age, perhaps because of 'unresolved behavioural problems'. McGreevy and McLean (2005) stressed the need for physical causes of undesirable behaviour to be ruled-out before behavioural therapy was adopted. They noted that bits are '...a potential source of tremendous discomfort'.

The horse is motivated to avoid pain and seek comfort. Mankind has an obligation to promote positive emotions for the horse – the neuroscience-supported concept (see **Table 1**) of 'positive affective engagement' (Mellor 2015a). Contingent on the absence of pain a horse can probably derive pleasure from being ridden, similar to that derived from 'play' with conspecifics (Mellor 2015b). Bonding between horse and rider seems optimal when rein cues are devoid of pressure, painless and proprioceptively supportive (Hanson and Cook 2015).

Limitations of the study

Study design

The case-study population was not a random population.

Questionnaire

The prototype questionnaire does not meet recently developed standards for questionnaire-based research (Hall *et al.* 2013; Muir 2013; Reid *et al.* 2013). A future questionnaire could be based on the Five Domains Model (Mellor and Stafford 2001; Jones and McGreevy 2010; Mellor and Beausoleil 2015; Mellor 2017). Future questionnaires might also include input from the work of Mullard *et al.* (2017) and Dyson *et al.* (2017) who have developed a ridden horse ethogram based on facial expression. Most recently, Dyson *et al.* (2018) have developed a pain scoring ethogram for the ridden horse with the objective of differentiating lame from nonlame horses.

Assessors were not 'blinded'

Nevertheless, as recommended by current welfare science, the assessors were the people most familiar with the animals studied, having triple credentials as owners, caretakers and riders.

Data grading

A simple count of pain indices represents the most basic of welfare grading systems. As a result, the homocentric 'lack of control' carried no more weight than, for example, 'yawning'. Absence of relative weighting will have underestimated the harm of the bit. That said, current welfare science thinking recommends non-numerical grading (Mellor and Beausoleil 2015; Mellor 2017).

Standardisation

Lack of standardisation prevents this study from being compared with others, e.g. Hockenhull and Creighton (2013). To permit comparisons, a standard glossary (McGreevy *et al.* 2005), ethogram and protocol is needed. None of the 24 behavioural markers of pain in the ridden horse ethogram developed by Dyson *et al.* (2018) were identical in wording to the 69 markers of pain in the current study. However, many were clearly descriptions of the same behaviours. Comparisons cannot be made because of the terminology differences and because none of Dysons' 37 horses were assessed when bit-free. The authors concluded "None of the horses ... had evidence of oral pain".

Crib-biting, wind-sucking and other stereotypic behaviours in stabled horses

A footnote to the questionnaire read: "To date there is no evidence to link wind-sucking or crib-biting as problems that might be caused by the bit but it would be worth noting the occurrence of such items in case a pattern of correlation could be demonstrated". Six out of 66 horses (9%) were reported as showing stable-based stereotypic behaviour when bitted; four windsuckers, one wood-chewer and one self-mutilator. Information was not collected on whether this behaviour changed when the bit was removed. In a survey of stereotypic behaviour in a randomly selected population of 650 riding-school horses, 46 exhibited stereotypies (Normando *et al.* 2002). A statistically significant difference was recognised in the prevalence of stereotypies between stabled horses ridden Western style (9 out of 348 horses – 3%) and 'English' (37 out of 302 horses – 12%). The authors noted that "the latter employs more hand to bit contact".

Conclusions

When bitted, the median number of behavioural signs of pain per horse was 23. After being bit-free for a median period of 35 days, the median was 2. Removal of the bit reduced the prevalence of pain signals by 87%; showing the bit to be a predominant cause of pain in the population. The null hypothesis was refuted. Following the criteria proposed by Campbell (2013) for distinguishing use from abuse, removal of the bit in 65 horses minimised risk (for the rider) and prevented avoidable suffering (for the horse). In sum, 65 horses out of 66 benefitted from removal of a foreign body.

Authors' declaration of interests

No current conflict of interests have been declared.

Ethical animal research

No ethical review was required.

Source of funding

There was no formal funding for this research. The data were collected by W.R. Cook during a period of years when he was the CEO of a small company, Bitless Bridle Inc. The costs, small as they were, were part of the general running costs of the company and did not figure in any line item for research in the annual accounts.

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Authorship

The study design was conceived by W. R. Cook, as was the execution, data entry and preparation of the manuscript. The statistical data analysis was carried out by M. Kibler. Both authors approved the final manuscript.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Supplementary Item 1: Questionnaire.

Supplementary Item 2: Prevalence of five major categories of fear in 66 horses compared by their order when bitted.