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The use of mirrors for the control of stereotypic weaving behaviour in the stabled horse

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Abstract

Weaving, a common locomotor stereotypy, has been associated with social isolation in stabled horses. In this study we investigated the effect of provision of mirrors on weaving as this may have a similar effect to access to conspecifics. The behaviour of six known weavers, each in one of three locations within a working equine yard, was recorded, 5 days a week for 12 weeks. After a pre-trial period of a week, one horse in each of the three locations was provided with a 1 m × 1.5 m mirror for 5 weeks, after which time the mirrors were removed and placed in the stables of the other three subjects for the next 5 weeks. All mirrors were then removed and the horses observed for a final week (post-trial period). The provision of a mirror significantly reduced the incidence of both stereotypic weaving ($P < 0.001$) and nodding ($P < 0.05$) for the 5 weeks of treatment but did not affect the time the horses spent standing active, dozing or ingesting. The mirror may mimic visual contact with conspecifics (minimising the social isolation of the stable) and/or provide environmental distraction or additional visual stimuli, altering the horses' perception of the environment and their resultant responses to it. The use of mirrors in the stable appears to be a more effective treatment of weaving than many current popular treatments, including weaving bars.

Keywords: Horse; Housing; Mirror; Stereotypy; Weaving

1. Introduction

Over 15% of domesticated horses have been reported to exhibit what are commonly termed 'stereotypies' (Luescher et al., 1991). Stereotypic behaviour has been defined as behaviours which are ''repetitive and invariant with no obvious goal or function'' (Mason, 1991a) and can be indicative of a situation in which the animal lacks a certain degree of control over its environment (Winskill et al., 1995; Fraser and Broom, 1990). One example

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of such behaviour in horses is a locomotor stereotypic activity known as weaving (Ralston, 1982) which is characterised by an obvious lateral swaying movement of the head, neck, forequarters and sometimes hindquarters (McGreevy et al., 1995a). Weaving is a relatively common stereotypy with its incidence in thoroughbred stables reported to be 2.54–4% (Luescher et al., 1998; McGreevy et al., 1995a) and its prevalence in dressage, eventing and endurance horses reported to be 9.4, 9.5 and 3.9%, respectively (McGreevy et al., 1995b). Aside from its aesthetic appearance, weaving is disliked by trainers and owners as it is believed to cause uneven muscular development in the neck, weight loss and fatigue, which in turn can affect a horse's performance (Winskill et al., 1995; Fraser and Broom, 1990). It is also a cause for welfare concern (Mason, 1991b).

In the treatment of any behaviour problem, it is preferable to identify and address the causal factors, rather than simply prevent the behaviour (Cooper and Mills, 1997). Nevertheless, physical barriers are probably the most frequently used treatment for weaving, in the form of anti-weave bars that attach to the stable door and restrict the horse's movement (Cooper and Mason, 1998). Although these may reduce the amount of 'head out of door weaving', the horse may continue to weave out of sight, inside the stable (McBride, 1996) or be frustrated further (Mills and Nankervis, 1999).

Horses are naturally free-ranging, social, grazing herbivores and their opportunity for social interaction is often limited in the domestic situation (Cooper and Mason, 1998). It has been suggested that weaving may be a response to the confinement of the stable and the frustrated motivation of horses attempting to reinstate social contact (Nicol, 1999). Therefore, increasing their opportunities to socialise may reduce the incidence of stereotypic behaviour (Cooper and Mason, 1998). An ideal way to achieve this would be to turn the stabled horse out to grazing where it can exercise and forage whilst mixing with other horses (Houpt and McDonnell, 1993; Cooper and Mason, 1998). This, however, is not always possible due to certain constraints like bad weather, lack of grazing and the value of the horse (Henderson et al., 1997).

Cooper et al. (2000) investigated the importance of social factors by altering the stabled horse's visual horizons to provide a view into a neighbouring horse's stable through an internal grill and found a significant decrease in weaving behaviour under that treatment regime. Unpublished pilot studies (cited by Nicol (1999)) suggested that the provision of a mirror might mimic visual contact and therefore help to reduce social isolation in the stable. This hypothesis was further investigated by Mills and Davenport (2002) who observed the behaviour of known weavers exposed to a mirror on the stable wall and found a significant decrease in weaving when compared to an unmodified stable. During this trial, the horses were exposed to the mirrors for a period of 1 week in an isolated stable block. The aim of this study, therefore, was to record the behaviour of known weavers with exposure to mirrors over a longer period (5 weeks) in a more typical equine yard, in order to evaluate the external validity of this putative treatment.

2. Materials and methods

2.1. Experimental subjects and general management

Six horses, five of Thoroughbred type and one Cleveland Bay, were used in this study. Of these, four were geldings and two were mares. The horses were housed at the De Montfort

University Equestrian Centre in Caythorpe, Lincs, UK. All had been known to exhibit weaving behaviour for at least 2 years. The experiment was carried out over a 12-week period. This consisted of a 1-week pre-trial period, when the horses were housed in their experimental stables without any exposure to mirrors. This was followed by a 5-week experimental period when three horses were provided with mirrors and three not. A second 5-week period followed this, immediately prior to which the mirrors were removed from the first cohort and placed in the stables of the other three subjects. Finally, there was a week-long post-trial period during which none of the experimental horses were provided with mirrors.

Since the study took place on a working equestrian centre, management practices varied over the course of the study. During the first 8 weeks of the trial, the horses were brought in from the field at 8.00 h, received a concentrate feed at 11.00 h and haylage at 11.30 h. At 16.00 h the horses were returned to the pasture where they remained until the following morning. In Week 8 of the trial, there was a change in the horses' management regime, which was associated with the students' return to the university. The horses were stabled almost full time with Horses 1, 2 and 5 given access to grazing for approximately 2 h a day and Horses 3, 4 and 6 exercised for 1–2 h a day. All received three concentrate feeds and three haynets a day at 7.00, 12.00 and 17.00 h.

2.2. Experimental apparatus

Three types of loose box were used in this trial (Fig. 1). The first of these (Stable Type 1) were two 3.5 m × 3.5 m stables with timber panel and metal grill fronts and sliding doors with built-in anti-weave bars (Lodden Livestock Equipment, Lodden). These stables provided Horses 1 and 2 with a limited view of the centre of activity of the yard. The second type (Stable Type 2) were two standard 3.5 m × 3.5 m timber loose boxes with traditional two-part stable doors and windows to the front. These were at the entrance of the yard and provided Horses 3 and 4 with a more frequent view of other horses and a greater amount of daily yard activities. The third type (Stable Type 3) were large brick stables (3.5 m × 7 m) with traditional split stable doors and windows to the front. These were outside the main body of the yard and visually isolated, giving Horses 5 and 6 no opportunities to view other horses or yard activities, although some activities could still be heard. All stables were bedded either with paper (Stable Type 2) or straw (Stable Types 1 & 3) according to the horses' normal management.

2.3. Behaviour categories

The horses were observed during a pilot study so that an ethogram of their position within the stable and their activity could be compiled. The horses' position was recorded as follows:

- Head over stable door—horse standing at stable door with its head over the door, looking out of the stable.
- Inside stable door—horse standing close to and facing the stable door with its head inside the stable.

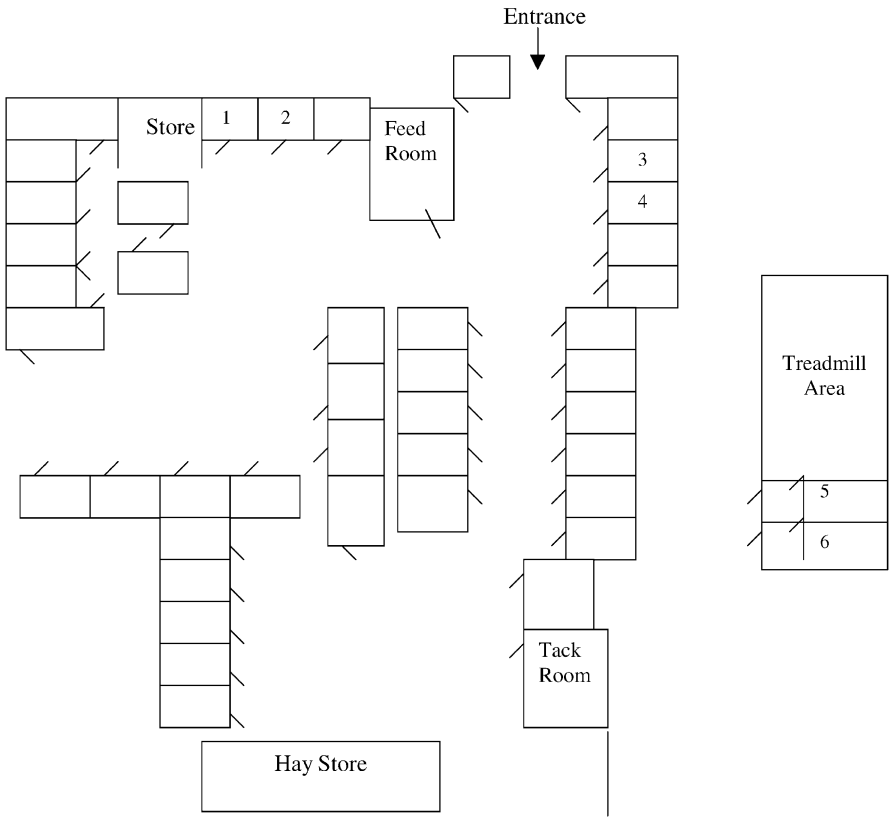

Fig. 1. The layout of the stables at the equine yard, the numbers illustrating horse number and their location.

- Facing the mirrored side—horse orientated towards the side of the stable with the mirror on it.
- Front window—horse orientated towards the front window of the stable or the front grill in the case of the grill and timber boxes.
- Facing a plain stable side—horse orientated towards a plain wall (i.e. with no mirror, window or door).
- Other position—horse in a position that cannot be classified by any of the above.

The horses' activity was recorded according to one of the following categories

- Weaving—an obvious lateral swaying movement of the head, neck, forequarters and sometimes hindquarters (McGreevy et al., 1995a).
- Other stereotypy—any other repetitive behaviour of a stereotypic nature (e.g. nodding, box-walking, crib-biting).
- Alert—rigid stance, with the neck elevated and the head orientated toward the object of focus. The ears are held stiffly upright and forward and the nostrils might be slightly dilated (McDonnell and Haviland, 1995).

- Dozing—horse standing motionless with eyes closed or semi-closed (Cooper et al., 2000).
- Lying down—sternal or lateral recumbency (Cooper et al., 2000).
- Ingestion—horse is actively chewing and swallowing food/edible material.
- Olfactory investigation—horse is actively sniffing a physical object including another horse.
- Muzzling—horse is actively touching/investigating a physical object with its muzzle.
- Head rubbing—horse is rubbing its head on some physical object.
- Ears laid back/pinned—ears pressed caudally against the head and neck (McDonnell and Haviland, 1995).
- Head threat—head lowered with the ears pinned, neck stretched or extended toward the target (McDonnell and Haviland, 1995).
- Other activity—horse performing an activity not listed above.

2.4. Pre-trial observations: Week 0

All horses were observed for a period of 4 days in their allocated stables (pre-treatment week) to gather baseline data before any treatment was applied. On the first 2 days, there were three observation periods: early morning (9.00–10.00 h) following re-introduction to the stable from pasture; mid-morning (10.00–11.00 h), around the morning feeding time when the horses received concentrated feed; and late afternoon (15.00–16.00 h) immediately prior to return to pasture from the stable. Previous studies on horses on a similar management regime (Cooper et al., 2000) had found weaving to be most common prior to feeding and prior to return to pasture. For Days 3 and 4 a further observation period, early afternoon (13.15–13.51 h) was also used; this was a time when the horses were largely undisturbed. Behavioural data were recorded using a fixed interval, scan sampling technique, with each horse's position and behaviour recorded at 4-min intervals for the duration of each observation period.

2.5. Mirror trial observations: Weeks 1–5 and 6–10

After this time, 1 m × 1.5 m acrylic mirrors (Riverside Glass, Newark, Notts) were fitted to the walls, approximately 1 m inside the door and 1.5 m from the floor, of the stables containing Horses 1, 4 and 5. The horses were observed 5 days a week for 5 weeks (Part 1). Each day there were four observation periods: 9.00–10.00 h (early morning), 10.00–11.00 h (late morning), 13.15–13.51 h (mid-afternoon) and 15.00–16.00 h (late afternoon). For Part 2, which immediately followed this, the mirrors were removed and placed in an equivalent location in the stables of Horses 2, 3 and 6. Once again, the horses were observed five times a week for 5 weeks using the same observation periods (Table 1).

In order to assess the reliability of the scan sampling data collection technique used, the horses' behaviour was recorded continuously from video recordings made for 1 day on each pair of horses in the three stable locations during the final week of both Part 1 (Week 5) and Part 2 (Week 10).

Table 1
Treatment schedule for the 12 weeks of the trial

Stable Type	Horse no.	Week 0/pre-treatment	Weeks 1–5/Part 1	Weeks 6–10/Part 2	Week 11/post-treatment
1	1	0	1	0	0
1	2	0	0	1	0
2	3	0	0	1	0
2	4	0	1	0	0
3	5	0	1	0	0
3	6	0	0	1	0

0: no mirror; 1: mirror.

2.6. Post-trial observation: Week 11

In the week following the end of Part 2, the mirrors were removed and all six horses were observed for a further week (post-treatment week). This observation ran for five successive days and used the same four observation periods as the previous run.

2.7. Analysis of data

The data were analysed in Minitab 12. For analysis, the number of scans of each category of activity and position was calculated as a proportion of the total number of scans for each observation. Data from the pre-trial observation were analysed using a repeated measure general linear model analysis of variance (GLM) with day of week and time of day as factors, blocked by individual horse. The effect of treatment (mirror) on the horses' behaviour during the trial observations was also assessed using a repeated measure GLM with data blocked by individual horse and week (1–5), time of day (early morning, mid-morning, early afternoon and late afternoon) and mirror treatment as factors. The behaviour of horses in the pre- and post-trial weeks was also compared using repeated measure GLM, again blocking by horse, with week (pre- versus post-trial) and time of day as factors.

The data from the videos were compared with the scan data using the Pearson's product moment correlation coefficient and the *t*-test. The data were grouped according to treatment and the factors assessed were % scans and % actual time weaving and with head over the door.

3. Results

3.1. Pre-trial observation

During the pre-trial week horses spent on average 39% (individual horse range (IHR) 33.6–47.9%) of scans facing a plain side of the stable (no mirror, window or door), 34% (IHR 10.7–52.9%) of scans with head over door, 13% (IHR 3.1–20.7%) of scans inside the

door, 9% (IHR 0.5–15.2%) of scans facing the front window and 4.4% (IHR 0.5–9.1%) of scans in an unclassified position. Standing active and standing dozing were the most common activities, occupying on average 20% (IHR 14.1–24.8%) and 43% (IHR 35.7–49.8%) of the horses' time, respectively. Horses spent a mean total of 6.8% of scans on stereotypic behaviour with weaving occupying 5.6% (IHR 0.9–15.2%) of scans and other stereotypies making up a further 1.2% (IHR 0–3.3%). Two other stereotypic activities were observed. Horses 1–4 performed nodding (repeated, exaggerated, bobbing up and down of the head; Fraser and Broom, 1990). Box-walking (a form of stereotypic pacing, in which the horse constantly walks around the perimeter of the stable; (Winskill et al., 1995) was also observed in Horse 4. The rest of the time was spent ingesting (mean 19% of scans, IHR 1.4–26.9%), head rubbing (mean 1.2%, IHR 0–1.7%), performing olfactory investigation (mean 1.2%, IHR 0.5–1.7%) or an unclassified activity (mean 6.4%, IHR 0–11.4%), with lying down, muzzling and head threat only occupying a small part of observation periods (mean 0.9%, IHR 0–1%). Ears laid back was not recorded in any of the observations during this week.

There was no significant effect of day of week on the horses' position or activities but time of day had a significant effect on the horse's position and on both stereotypic and non-stereotypic activities (Table 2). The horses appeared to be more active in the mid-morning and late afternoon periods with a higher percentage of scans for alert, weaving and head over door and a lower percentage of scans for dozing than in the early morning and early afternoon periods. Horses appeared to weave least in the quieter early morning and early afternoon observations, but there was only a significant difference between data from early morning and mid-morning (Tukey's t-test; $t = 2.79$, $P < 0.05$). The only other significant change in behaviour between the observation periods was a higher incidence of

Table 2
The mean percentage (±S.D.) of scans for each activity and position during the four observation periods[a]

	Early morning	Mid-morning	Early afternoon	Late afternoon	$F_{3,72}$
% Behaviour					
Weaving	2.2 ± 0.01	9.2 ± 0.01	0.1 ± 0.02	8.3 ± 0.01	4.33**
Other stereotypy	0.0 ± 0.00	2.2 ± 0.00	0.1 ± 0.01	1.9 ± 0.00	2.28
Alert	17.4 ± 0.03	25.2 ± 0.03	6.7 ± 0.05	23.3 ± 0.03	5.17**
Dozing	56.4 ± 0.06	29.2 ± 0.06	53.3 ± 0.08	43.3 ± 0.06	5.54**
Ingestion	13.7 ± 0.05	16.5 ± 0.05	33.5 ± 0.07	11.2 ± 0.05	6.08**
Other activity	8.1 ± 0.04	12.3 ± 0.04	4.8 ± 0.06	7.0 ± 0.04	2.12
% Position					
Head over door	38.9 ± 0.05	37.8 ± 0.05	8.5 ± 0.06	34.7 ± 0.05	5.99**
Inside door	6.6 ± 0.03	12.7 ± 0.03	39.5 ± 0.04	6.9 ± 0.03	9.55***
Front window	5.9 ± 0.04	8.7 ± 0.04	2.4 ± 0.06	12.0 ± 0.04	1.42
Plain stable side	44.6 ± 0.06	27.7 ± 0.06	45.8 ± 0.09	44.3 ± 0.06	2.45
Other position	6.5 ± 0.04	11.8 ± 0.04	3.2 ± 0.06	1.8 ± 0.04	3.58*

[a] Test statistic F calculated from ANOVA.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

Table 3
The percentage (mean ± S.E.) of scans of behaviours and positions for all horses throughout the 12 weeks of the trial with and without the mirrors

	Mirror	No mirror	$F_{1,202}$
% Behaviour			
Weaving	0.1 ± 0.04	3.2 ± 0.37	70.09***
Other stereotypy	0.7 ± 0.01	1.1 ± 0.01	4.63*
Alert	20.8 ± 0.9	20.8 ± 0.9	0.00
Dozing	41.5 ± 1.4	40.5 ± 1.4	0.28
Lying down	0.4 ± 0.2	0.0 ± 0.00	3.41
Ingestion	25.0 ± 1.2	25.0 ± 1.2	0.02
Olfactory investigation	0.4 ± 0.00	0.4 ± 0.00	0.54
Muzzling	0.3 ± 0.00	0.2 ± 0.00	1.73
Head rubbing	0.5 ± 0.00	0.4 ± 0.00	0.14
Ears laid back	0.4 ± 0.00	0.5 ± 0.00	0.42
Head threat	0.0 ± 0.00	0.2 ± 0.00	6.88**
Other activity	9.8 ± 1.0	6.7 ± 0.8	5.45*
% Position			
Head over door	26.7 ± 1.2	30.1 ± 1.3	3.32
Inside door	8.7 ± 0.7	10.9 ± 0.9	3.78
Front window	7.5 ± 0.7	6.8 ± 0.7	0.50
Plain stable side	19.4 ± 1.0	45.3 ± 1.4	220.60***
Facing the mirror	27.6 ± 1.3	0.0 ± 0.00	472.50***
Other position	9.0 ± 1.0	6.3 ± 0.9	4.39*

ns: not significant.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

ingestion in early afternoon, following addition of haylage, compared with early morning (Tukey's t-test, $t = 3.68$, $P < 0.01$), mid-morning ($t = 3.19$, $P < 0.05$) and late afternoon ($t = 4.12$, $P < 0.001$).

3.2. Mirror trial observations

The primary effect of placing mirrors in stables was a reduction in stereotypic weaving (Table 3). In the 5 weeks of treatment in both groups, those horses with the mirror were rarely scanned weaving in any of the four observation periods ($0.1 \pm 0.04\%$), whereas those horses without mirrors continued to weave frequently ($3.2 \pm 0.37\%$) (Fig. 2). There was also an effect of mirror on other stereotypies with less nodding (this was the only other stereotypy which was recorded between Weeks 1 and 10) when a mirror was present (Table 3). The presence of mirrors had no effect on frequent activities such as standing active, dozing and ingestion, though there was a significantly lower incidence of less common activities such as head-threat and unclassified activities.

The mirror also appeared to affect the horses' orientation within the stable. There was no effect of mirror on apparent time spent with head over door or orientation towards door or

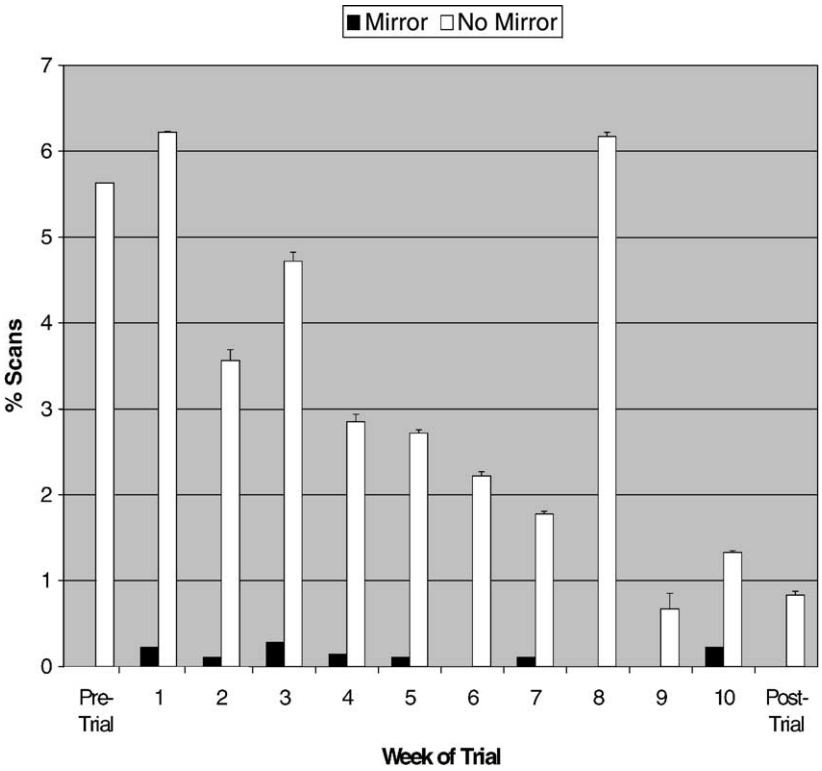

Fig. 2. The percentage of scans (mean ± S.D.) observed in stereotypic weaving for all horses with and without mirrors during the 12 weeks of the trial.

window, but horses with mirrors appeared to favour an orientation towards the mirror with 28% of scans out of a total of nearly 55% of scans inside the stable directed towards the mirror.

3.3. Effect of week and week of treatment

There was a significant effect of week on both position and activity ($P < 0.05$ for head threat, $P < 0.01$ for weaving and $P < 0.001$ for all others) except for lying down ($F = 0.79$, $P > 0.05$). There was also a significant effect of week of treatment (1–5) on most positions and activities ($P < 0.01$ for facing the front window, $P < 0.05$ for active and 'other positions' and $P < 0.001$ for all others, except for 'other behaviours' or other stereotypies ($P > 0.05$). Graphical representation (Fig. 3) illustrates similar trends in the number of scans observed for facing the mirror across the weeks of treatment for Horses 1, 4, and 5 who were exposed to the mirrors in the quiet period (Part 1). This same pattern was observed in Horse 6 who encountered the mirror in Part 2. This horse was in one of the visually isolated stables so would not have had the same stimuli to contend with as the other horses. There was however no correlation between scans for facing the mirror and scans

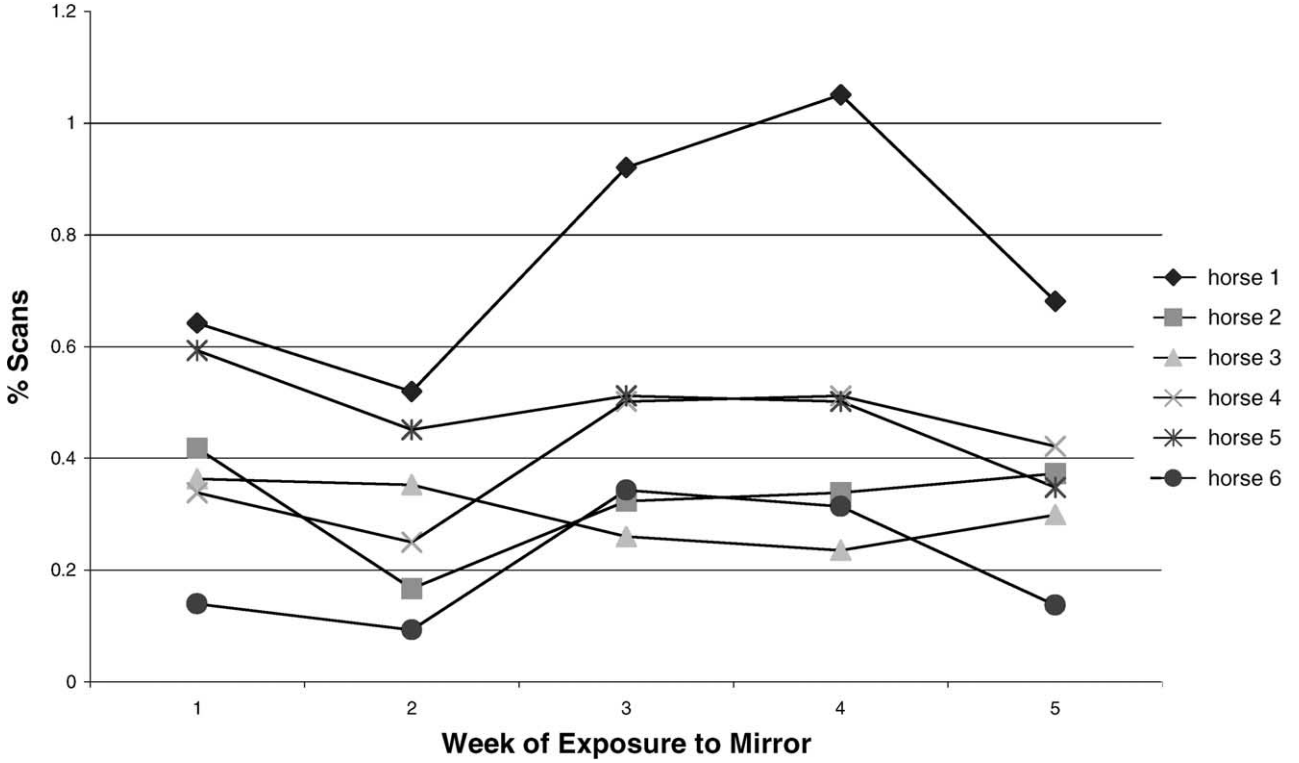

Fig. 3. The mean percentage of scans observed facing the mirror for each horse for each week of exposure to the mirror.

Table 4
The mean percentage (±S.D.) of scans for each activity and position during the four observation periods[a]

	Early morning	Mid-morning	Early afternoon	Late afternoon	$F_{3,72}$
% Behaviour					
Weaving	1.3 ± 0.36	2.4 ± 0.35	0.7 ± 0.35	2.4 ± 0.35	5.81**
Other stereotypy	0.9 ± 0.00	1.3 ± 0.00	0.4 ± 0.00	1.0 ± 0.00	2.92*
Alert	24.0 ± 0.01	24.8 ± 0.01	11.2 ± 0.01	23.2 ± 0.01	30.46***
Dozing	33.3 ± 0.02	29.7 ± 0.02	53.9 ± 0.02	47.2 ± 0.02	43.33***
Ingestion	28.5 ± 0.01	31.4 ± 0.01	23.9 ± 0.01	15.6 ± 0.01	23.0***
Other activity	9.3 ± 0.01	7.6 ± 0.01	8.1 ± 0.01	7.9 ± 0.01	0.41
% Position					
Head over door	34.5 ± 0.02	33.2 ± 0.02	15.6 ± 0.02	30.7 ± 0.02	33.39***
Inside door	6.3 ± 0.01	13.8 ± 0.01	13.1 ± 0.01	6.1 ± 0.01	19.20***
Facing mirror	11.2 ± 0.01	8.4 ± 0.01	19.8 ± 0.01	16.0 ± 0.01	18.22***
Front window	8.0 ± 0.01	7.8 ± 0.01	6.5 ± 0.01	6.4 ± 0.01	0.82
Plain stable side	30.4 ± 0.02	30.0 ± 0.02	36.2 ± 0.02	32.8 ± 0.02	2.94*
Other position	8.5 ± 0.01	6.4 ± 0.01	8.6 ± 0.01	7.2 ± 0.01	0.72

[a] Test statistic F calculated from ANOVA.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

weaving (Pearson's correlation, $r = -0.109$, $P > 0.05$). A different pattern was observed during part two for the horses housed in the busier part of the yard.

3.4. Effect of time of day/observation period

As in the pre-treatment week, time of day had a significant effect on the horses' position and on both stereotypic and non-stereotypic activities (Table 4). The horses appeared to be most active in the early morning, late morning and late afternoon periods with a higher percentage of scans for alert and head over door and a lower percentage of scans for dozing at this time than in the early afternoon periods. Horses appeared to weave least in the quieter early afternoon observations, compared with mid-morning, prior to feeding in both runs (Tukey's t-test, $t = 2.173$, $P < 0.01$) and compared with late afternoon, prior to return to pasture in the first 7 weeks and prior to feeding for the last 5 weeks of the trial ($t = 3.351$, $P < 0.01$).

3.5. Pre-trial week versus post-trial week

There was a difference in weaving between the pre-trial (mean 4.9%) and post-trial weeks (mean 0.8%) with significantly less observed in the post-trial week ($F = 15.22$, $P < 0.001$). There was also a significant reduction in other stereotypies between the pre-trial (mean 1%) and post-trial (mean 0.1%) weeks ($F = 6.68$, $P < 0.05$). There were a small number of other differences in the horses' activities and positions between the post- and pre-trial weeks. There was a reduction in observations for head rubbing, olfactory investigation and inside the door ($P < 0.001$), of head over the door and dozing ($P < 0.01$)

and in muzzling ($P < 0.05$) in the post-trial week. There were significant increases in observations for ingestion ($P < 0.001$), facing a plain stable wall and facing the front window ($P < 0.05$) in the post-trial week.

3.6. Reliability analysis

There were significant correlations found between the video and scan data for: weaving behaviour with no mirror (Pearson's correlation, $r = 0.812$, $P < 0.001$), weaving behaviour with the mirror ($r = 0.938$, $P < 0.001$), 'head over door' with no mirror ($r = 0.984$, $P < 0.001$) and 'head over door' with the mirror ($r = 0.984$, $P < 0.001$). In addition, there were no significant differences found between the video and scan data for: weaving behaviour with no mirror (Paired t-test; $t = 1.17$, $P > 0.1$), weaving behaviour with the mirror ($t = 1.16$, $P > 0.1$), 'head over door' with no mirror ($t = 0.20$, $P > 0.1$) and 'head over door' with the mirror ($t = 1.55$, $P > 0.1$). The analysis of the scanning technique used showed it to be a valid, reliable method, giving accurate predictions of the actual time the horses spent weaving during the observation periods.

4. Discussion

The provision of a mirror reduced the incidence of stereotypic weaving in stabled horses that had been known to weave for at least 2 years when compared with their behaviour in unmodified stables. The horses spent a large proportion of their time within the stable orientated towards the mirror (28% of scans) but there was no significant effect observed on other activities such as standing active, dozing and ingesting. There was also a decrease in other potentially undesirable behaviours, namely head nodding and head threats. This latter finding may be particularly worthy of further investigation. Both stereotypy and aggression are believed to be a common consequence of frustration in the horse (Mills and Nankervis, 1999) and other species (Duncan and Wood-Gush, 1971) so these effects may be the consequence of the relief of frustration underlying the behaviour.

Throughout the study, the majority of weaving was observed in the mid-morning and late afternoon periods, which is consistent with weaving occurring largely as an anticipatory stereotypy with a peak in weaving often recorded prior to feeding (Henderson et al., 1997; Cooper et al., 2000). The mid-morning period preceded feeding of hay and concentrates for the duration of the study and the late afternoon period preceded turnout to grazing in the first part of the trial and feeding in the latter part. There was significantly less weaving observed in the afternoon period. During this time there was little environmental disturbance, which is not consistent with the view that stereotypic behaviour in horses is associated with boredom as has been suggested by some authors (e.g. Kiley-Worthington, 1987).

There were also effects of week of observation on many of the behaviours of the horses in this study. Although the treatment (presence of the mirror) was the most significant factor in the reduction of weaving, other changes in the horses' management over the weeks also clearly had an effect. There was a substantial increase in weaving in Week 8 of the trial amongst those horses that did not have a mirror, which coincided with a number of

changes in the management regime. Notable amongst these was the reduced turnout time (from 18 to 0–2 h daily) which would not only limit opportunities to graze but also opportunities to socialise with conspecifics. From Week 8 onwards, the horses were also offered concentrate three times a day (as opposed to once a day prior to this) which has been associated with an increased risk of abnormal behaviour (McGreevy et al., 1995a). However, no horse with a mirror was seen to weave during this week. As this study took place on a large (42 horses), working equestrian centre over a long period of time, changes in the management were inevitable. Since the object was to evaluate the external validity of the treatment, we do not consider this a problem, but rather that it adds further robustness to our conclusions.

One concern raised over the introduction of treatments for weaving in previous studies was that the changes in the horses' behaviour could be a response to the novelty of the environment (Cooper et al., 2000). If so, the incidence of weaving would be expected to gradually increase over time. Whilst interaction with the mirrors did vary, a significant reduction in weaving was maintained throughout the 5 weeks of treatment. Consequently in this study we found no evidence for a reduction in the mirror's effect over time. Another concern with the prevention of undesirable behaviour is that animals might resume the behaviour with the same or greater intensity once the treatments are removed. Such a 'rebound' effect has been observed in a study investigating the effect of the prevention of stereotypic crib-biting in horses (McGreevy and Nicol, 1998) and is thought to reflect a rise in the internal motivation to perform the behaviour whilst it was being prevented. This obviously raises concern over the welfare implications of such treatments of behaviour problems. We observed no such effect and there was also a very clear reduction in weaving between the pre- and the post-trial week, when none of the horses had exposure to a mirror ($P < 0.001$).

A low level of weaving was observed in those horses with mirrors throughout the trial, both when the yard was quiet and when it became busier and in all stable locations, which would indicate that mirrors could be effective in a variety of yard situations. It is also worth noting that the treatment was effective in all cases, even though all horses had a reliable history of weaving behaviour of at least 2 years and in one case (Horse 4) of more than 6 years. Several authors have suggested that stereotypic behaviour may become emancipated with time (e.g. Mason, 1991a; Mills and Nankervis, 1999). This has been supported by experimental evidence in other species (Cooper et al., 1996). However, the results described here suggest that proximate environmental factors remain critical for the expression of stereotypic weaving behaviour in the horse.

As previously suggested, weaving may be a response to the frustrated motivation of stabled horses to socialise (Nicol, 1999) with visual and tactile contact with other horses being an important factor (Houpt, 1995; McGreevy et al., 1995a). Previous studies investigating the effects of internal grills allowing visual, tactile and chemical contact between horses in neighbouring stables found they caused significant decreases in the prevalence of weaving (Cooper et al., 2000). It has been suggested that horses may develop stereotypies as a result of observational learning (e.g. Kiley-Worthington, 1983). There is no clear evidence of this phenomenon in the horse (Baker and Crawford, 1986; Baer et al., 1983) although stimulus enhancement may occur as a result of conspecific activity (Clarke et al., 1996). If weaving is socially enhanced in any way, it might be expected that the provision of a mirror would exacerbate the problem as the weaver would observe weaving

behaviour whenever it engaged in it, leading to positive feedback. However, the opposite effect was found and, therefore, we conclude that it is more likely that horses within a yard develop similar stereotypies because they are subject to the same management practices (Nicol, 1999; Houpt and McDonnell, 1993; Winskill et al., 1995).

The mechanism whereby the mirror reduces weaving remains unclear. It may mimic the visual contact with neighbouring horses that an internal grill provides, minimising the social isolation of the stable (Nicol, 1999). The horses in this study had a degree of visual contact with several other horses within the yard (with the exception of Horses 5 and 6 who could only view each other over the stable door). This did not reduce weaving in itself, so if visual contact with other horses is a major factor, it could be the perceived proximity and/or activity of the social companion that is important. Alternatively, the mirror may have acted as an environmental distraction with the horses spending more of their time facing it rather than with their head over the door, where the majority of weaving occurs, thus reducing the opportunity to perform this activity. We think it is unlikely that the effects of the mirrors on weaving is due to a simple change in visual horizons as a previous study (Cooper et al., 2000) found no effect with this modification in the absence of social stimuli. However, it is possible that the mirror acts to reduce perceived confinement in some way not addressed by the stable modification of Cooper et al. (2000). If the effect of mirrors was to alter the horses' perception of the stable environment and consequently their behavioural responses to it, then the provision of mirrors to stabled horses could be of significant benefit to the subjects (Cooper and Mills, 1997) compared with conventional preventative measures. Treatment of weaving by physical restraint such as weaving bars may not only be ineffective at removing the underlying causes, leading the horse to persevere with the behaviour in a reduced or redirected form or to substitute one stereotypy for another (McBride, 1996), but may in itself affect the horses quality of life by frustrating a highly motivated activity (Cooper and Mason, 1998).

In conclusion, the presence of a mirror significantly reduced the incidence of weaving in stabled horses, as well as nodding and head threats. Whether the mirror mimics visual contact with conspecifics or provides visual stimuli or distraction to alter the horses' perception of the stable, it would appear to be a successful technique of environmental enrichment to reduce the consequences of the social frustration induced by the stable with no evidence of further welfare compromise in the patient.

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References

Baer, K.L., Potter, G.D., Friend, T.H., Beaver, B.V., 1983. Observation effects of learning in horses. Appl. Anim. Ethol. 11, 123–129.

Baker, A.E.M., Crawford, B.H., 1986. Observational learning in horses. Appl. Anim. Behav. Sci. 15, 7–13.
Clarke, J.V., Nicol, C.J., Jones, R., McGreevy, P.D., 1996. Effect of observational learning on food selection in horses. Appl. Anim. Behav. Sci. 50, 177–184.
Cooper, J.J., Mason, G.J., 1998. The identification of abnormal behaviour and behaviour problems in stabled horses and their relationship to horse welfare: a comparative review. Eq. Vet. J. Suppl. 27, 5–9.
Cooper, J.J., Mills, D.S., 1997. Welfare considerations relevant to behaviour modification in domestic animals. In: Mills, D.S., Heath, S.E., Harrington, L.J. (Eds.), Proceedings of the 1st International Conference on Vet. Behav. Med., UFAW, Potters Bar, UK, pp. 164–173.
Cooper, J.J., Odberg, F., Nicol, C.J., 1996. Limitations on the effectiveness of environmental improvement in reducing stereotypic behaviour in bank voles (*Clethrioonomys glareolus*). Appl. Anim. Behav. Sci. 48, 237–248.
Cooper, J.J., McDonald, L., Mills, D.S., 2000. The effect of increasing visual horizons on stereotypic weaving: implications for the social housing of stabled horses. Appl. Anim. Behav. Sci. 69, 67–83.
Duncan, I.J.H., Wood-Gush, D.G.M., 1971. Frustration and aggression in the domestic fowl. Anim. Behav. 20, 500–504.
Fraser, A.F., Broom, D.M., 1990. Farm Animal Behaviour and Welfare. Bailliere, Tindell.
Henderson, J.V., Waran, N.K., Young, R.J., 1997. Behavioural enrichment for horses: the effect of a foraging device (the 'Equiball') on the performance of stereotypic behaviour in stabled horses. In: Mills, D.S., Heath, S.E., Harrington, L.J. (Eds.), Proceedings of the 1st International Conference on Vet. Behav. Med., UFAW, Potters Bar, UK, pp. 204–208.
Houpt, K.A., 1995. New perspectives on equine stereotypic behaviour. Eq. Vet. J. 27, 82–83.
Houpt, K.A., McDonnell, S.M., 1993. Equine stereotypies. Comp. Cont. Edu. Pract. Vet. 15, 1265–1271.
Kiley-Worthington, M., 1983. Stereotypes in horses. Eq. Prac. 5, 34–40.
Kiley-Worthington, M., 1987. The Behaviour of Horses in Relation to Management and Training. JA Allen, London.
Luescher, U.A., McKeown, D.B., Halip, J., 1991. Reviewing the causes of obsessive-compulsive disorders in horses. Vet. Med. 86, 527–531.
Luescher, U.A., McKeown, D.B., Dean, H., 1998. A cross-sectional study on compulsive behaviour (stable vices) in horses. Eq. Vet. J. Suppl. 27, 14–18.
Mason, G.J., 1991a. Stereotypies: a critical review. Anim. Behav. 41, 1015–1037.
Mason, G.J., 1991b. Stereotypies and suffering. Behav. Proc. 25, 103–115.
McBride, S.D., 1996. A comparison of physical and pharmacological treatments for stereotyped behaviour in the horse. In: Duncan, I.J.H., Widowski, T.M., Haley, D.B. (Eds.), Proceedings of the 30th International Society on Appl. Ethol., CSAW, Guelph, Canada, p. 26.
McDonnell, S.M., Haviland, J.C.S., 1995. Agonistic ethogram of the equid bachelor band. Appl. Anim. Behav. Sci. 43, 147–188.
McGreevy, P.D., Nicol, C.J., 1998. The effect of short term prevention on the subsequent rate of crib-biting in thoroughbred horses. Eq. Vet. J. Suppl. 27, 30–34.
McGreevy, P.D., Cripps, P.J., French, N.P., Green, L.E., Nicol, C.J., 1995a. Management factors associated with stereotypic and redirected behaviour in the thoroughbred horse. Eq. Vet. J. 27 (2), 86–91.
McGreevy, P.D., French, N.P., Nicol, C.J., 1995b. The prevalence of abnormal behaviours in dressage, eventing and endurance horses in relation to stabling. Vet. Rec. 137, 36–37.
Mills, D.S., Davenport, K., 2002. Evidence for the importance of visual stimuli in the control of equine weaving behaviour. Anim. Sci. 74, 95–101.
Mills, D.S., Nankervis, K.J., 1999. Equine Behaviour: Principles & Practice. Blackwell Scientific Publications, Oxford, UK.
Nicol, C.J., 1999. Understanding equine stereotypies. Eq. Vet. J. Suppl. 28, 20–25.
Ralston, S.L., 1982. Common behaviour problems in horses. Comp. Cont. Ed. Pract. Vet. 4, 152–159.
Winskill, L.C., Waran, N.K., Young, R.J., 1995. Stereotypies in the stabled horse: causes, treatments and prevention. Curr. Sci. 69, 310–316.