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Stall architecture influences horses' behaviour and the prevalence and type of stereotypies

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A R T I C L E I N F O

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A B S T R A C T

Despite the spatial and social restrictions it causes, single stall housing still prevails in sport and riding school horses, leading to the emergence of abnormal behaviours such as stereotypic or abnormal repetitive behaviours (SB/ARB). In the present study, we investigated the impact of the type (visual/tactile) and amount of social information that could be exchanged (*i.e.* distance between the individuals) on the expression of welfare indicators, including, but not limited to, STB. Additional observations were made on the production of snorts, recently described as a potential indicator of positive emotions, according to the type of stall horses were housed in. Two complementary studies were performed. One observational study on 32 sport horses, all living in the same place, being of the same breed and sex, whose aim was to compare the behaviours of horses maintained for a long time in two types of stalls differing mostly in the possibilities of contact with close neighbours *versus* looking outdoors. The second, experimental study, consisted in moving purebred Arab broodmares from one condition to another randomly every day for 66 days, the two types of stalls differing only by the possibility or not to put the head outside above the open top half door. The results show clear statistical relations between stall architecture and horses' behaviour, especially STB, their prevalence and type differing according to the type of stall in both studies. Overall, the access to outdoor visibility and its degree (possibility to put the head out or not) had a major effect on the horses' behaviours, which was the same in both studies, despite the differences between populations in terms of breed, sex and type of work. The experimental study also reveals that changes in behaviours can be rapid after a change of housing.

1. Introduction

Constant single stall housing (*e.g.* more than 20 h/day) remains predominant in the global horse industry, and more particularly in sport and riding schools horses, and was related to the prevalence of stereotypic or abnormal repetitive behaviours (SB/ARB in the following manuscript) in questionnaire-based (*e.g.* McGreevy et al., 1995) and observational (Lesimple et al., 2016) epidemiological studies.

Beyond spatial, hence movement, restriction, this housing is also associated with a lack of social contact, one of the major sources of emergence of stereotypic behaviours in social captive/domestic species (*e.g.* Mason, 1991). Parent-raised parrots, when separated, develop stereotypies when singly housed but not if they are housed in pairs (Meehan et al., 2003). Similarly, Visser et al (2008) found, in young horses stabled for the first time, that 67% of young warmblood horses housed in single stalls developed stereotypic behaviours in the two first weeks after their first stall housing while pair housed animals did not. Moreover, the singly housed young horses were more agitated (increase of vigilance, neighing, pawing, nibbling) while paired horses spent more time eating. A study on adult mares also showed that broodmares with foals, thus having social interactions, expressed 5 times less stereotypic behaviours than their without-foal neighbours housed in the same conditions (Benhajali et al., 2010). Singly housed horses and starlings are ready to "work" to obtain direct (Lee et al., 2011), even if

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partial (Sondergaard et al., 2011) or mimicked (picture: Perret et al., 2015) social contact. In a variety of species (long tailed macaques: Crockett et al., 1994; baboons: Kessel and Brent, 2001), the increase of social opportunities also decreases the frequency of STB, even if social opportunities are slight (horses: naso-nasal/visual contact, Cooper et al., 2000; Mills and Davenport, 2002), or mimicked (horses: mirror: Kay and Hall, 2009; Mills and Davenport, 2002, conspecific picture: Mills and Riezebos, 2005). In horses, this is also associated with a decrease of stress and excitation behaviours (vigilance, active locomotion) and an increase of behaviours reflecting calmness (resting, foraging), even in horses with a long history of stereotypic behaviours (*e.g.* weaving, Mills and Davenport, 2002). It is well admitted that SB/ARB reflect chronic stress in captive and domestic animals (Mason, 1991) and hence are reliable indicators of compromised welfare. In horses, the expression of SB/ARB is associated with lowered cognitive abilities (Hausberger et al., 2007; Parker et al., 2008) and fertility (Benhajali et al., 2010). Thus, despite the fact that STB may help horses cope (Fraser et al., 1997), their efficiency in terms of coping remains to be demonstrated (*e.g.* Fureix et al., 2013).

On the other hand, horses are also ready to work for access to a paddock even if alone as compared to being in a single stall, showing that movement restriction, and especially free movement (no motivation for constrained locomotion) is also a behavioural /physiological need (Lee et al., 2011; Gorecka-Bruzda et al., 2013). It has been proposed that captive laboratory animals, that experience high levels of spatial restriction, appear to develop motor STB related to flight attempts (mice: Lewis and Hurst, 2004; Würbel et al., 1996, 1998, starlings: Feenders and Bateson, 2012). Similarly in horses, it has been suggested that weaving, a well-known locomotor stereotypic behaviour, would particularly reflect the frustration of not being able to go out of the stall (Mills, 2005).

Several authors stated that the nature and degree of frustration experienced might modulate the emergence, type and prevalence of STB. For example, Bergeron et al. (2006) proposed that oral STB are mostly related to feeding frustration. In horses, beyond some potential genetic sensitivity (*e.g.* reviews in Houpt and Kusunose., 2001; Hausberger and Richard-Yris, 2005), large discrepancies have been found in terms of type and prevalence of stereotypies between studies or facilities (Lesimple and Hausberger, 2014), that cannot be solely attributed to breed effects. Thus, different types of STB were found according to the type of work, horses of a same sex and breed (all selected from show jumping bloodlines) living in a same site (with identical life conditions) performed. Dressage horses, that experience higher constraints at the head/mouth level, performed more STB, and especially more repetitive head movements (head shaking/tossing/nodding), potentially associated with nuchal ligament lesions (Cook, 1999, 2003), and cribbing/windsucking, potentially related to teeth and gastric disorders (Mills, 2005). However, vaulting, eventing and jumping horses performed less and "milder" forms of stereotypies (repetitive licking, tongue movement) (Hausberger et al., 2009). Ödberg (1978) in particular, proposed that stereotypic behaviours emerge through the repetition of actions aiming at reducing the frustration/discomfort, leading to chronic repetition of particular behaviours. This could explain why different types of repetitive behaviours may emerge as a consequence of the type of restriction the individual experiences. Overall, these findings suggest that there is indeed flexibility in the expression of these behaviours and that changes in the environment may be associated not only in changes in the frequency but also in the types of stereotypic behaviours.

Environmental "enrichments" are often proposed but in order to be efficient, they need to correspond to the animal's needs (*e.g.* Mason, 1993). Thus, increasing cage size did not prevent young gerbils from developing stereotyped sand digging, whereas providing an adequate burrow substitute, even in a small cage, did (Wiedenmayer, 1996a, 1996b). Raised resting platforms, added as environmental enrichment in the cages of shelter dogs and young silver foxes, were derived from their initial purpose and mostly used by the animals to obtain a visual access to the neighbours (dogs: Hubrecht 1993, silver fox: Monomen 1933 in Newberry, 1995). Increasing visual horizons, and in particular providing a view of the outdoors, either real or as videos resulted in an increase of locomotor STB in starlings (Feenders and Bateson, 2012; Coulon et al., 2014). In horses, providing a visual access to the outdoors -and potentially to unreachable congeners- led to an increase of vigilance (*i.e.* alarm posture, Kiley-Worthington, 1976) (Cooper et al., 2000), and appeared amongst the primary factors of STB emergence in an epidemiological observational study conducted on more than 300 horses (Lesimple et al., 2016).

Only few experiments, often conducted on a small number of horses, investigated how stall architecture (visual horizon and type and amount of social opportunities) impacts horses' behaviour. With the present study, we hypothesized that the visual horizon and the type of social contact (visual/tactile, distant/close) provided modulates horses' behaviour and especially the expression of welfare indicators, in particular the type and frequency of STB. In order to test this hypothesis, we performed two main studies: (1) an observational study on 32 sport horses of same sex, breed and discipline living at a same facility (same management conditions) but housed in two different types of stalls: Open Stalls (OS, possibility to put their head out), or Grid Stalls (GS), enabling to see close neighbours but with no outside view); (2) an experimental study on 42 broodmares of same breed, living at a same facility (same management conditions), spending the day in paddocks and nights in single stalls. For the study, they were randomly assigned for the night in one out of two types of "external" stalls: Open Stalls (OS, possibility to put their head out) or Grid Stalls (GS, no possibility to put their head out). In addition, and given the recent discovery of a putative acoustic indicator of well-being (Stomp et al., 2018), we added a short later study on acoustic signals produced according to stall architecture on site 1.

2. EXPERIMENT 1: observational study in sport horses

In order to detect a potential effect of stall architecture on horses' welfare, we first conducted observational studies in horses that had lived for at least 6 months in the same type of stall. All horses included in the two sessions were under the care of the veterinarian of the Ecole Nationale d'Equitation (Saumur, France) and were free from any health disorder.

2.1. Material & methods

2.1.1. Session 1: behavioural observations

2.1.1.1. Subjects and housing conditions. Thirty-two French Saddlebred geldings, aged 6–19 years ($\bar{X} \pm se = 10.03 \pm 0.12$), all working in dressage, were observed at the "Ecole Nationale d'Equitation" (ENE) at Saumur in August 1994. Horses were kept in straw bedded single stalls, fed three daily concentrate meals, provided hay once a day (morning), with *ad-libitum* water access. All of them also had 1 hour riding exercise every day.

Thus, all horses shared the same environmental conditions, were of the same sex and breed with management condition differing only in terms of type of stalls they lived in, while the surfaces of the stalls were similar (9.75 m^2 for type 1 stalls, 9m^2 for type 2 stalls). Open Stalls (OS, N = 17 horses) (Fig. 1a) had limited openings (3.35 m^2) consisting of a small side window (0.49 m^2) with grid that allowed horses to see one neighbour and mostly the open front half door (2.86 m^2) enabling the horse to have its head outside. This opening gave a view over the outdoor riding arena and horses being led from their stall to the working areas and back. Grid Stalls (GS, N = 15 horses) (Fig. 1b) were located in an indoor barn with no outdoor openings, but half side walls replaced with grids, enabling sight and nose to nose contact with their two neighbours, as well as a grid above their door, enabling sight of neighbours across the corridor: they could see therefore more than 5

Fig. 1. Stall architecture in Study 1 (a) Open Stall (OS), (b) Grid Stall (GS).

neighbours (1 on each side and 3 in front at least). This constituted a surface of 11.76m^2 openings. Thus, OS stalls favoured a vision of the outside world while GS stalls favoured social visual and olfactory (and some tactile) contacts at close range. All horses had been in this same stall for more than 6 months when the study started.

2.1.1.2. Data collection. Each horse was observed during 10 to 11 5-minutes sessions distributed in the morning (08:00 to 11:00 a.m.), in the afternoon (01:00 to 04:00 p.m. and 05:00 to 07:00 p.m.) and before meals using the continuous focal sampling method (Altman, 1974), yielding 50 to 55 min observation per horse (mean: 54.22 ± 1.84 min/horse). The same observer (EG) recorded all the observations through a voice recorder while standing outside the stall (see also Fureix et al., 2011). This same experimenter had been performing observations regularly in the previous months, horses were thus habituated to his presence. The time of observation of a given horse changed every day following a rotation schedule (thus if one horse was observed from 05:00 p.m. to 05:05 p.m. on day 1, it was observed between 05:05 p.m. to 05:10 p.m. on day 2, *etc*). All behaviours were noted (Table 1), and the frequency of observation was evaluated for each behaviour as the number of occurrences divided per the time of observation (giving a number of behaviour observed per minute). Stereotypic and abnormal repetitive behaviours (STB) were identified according to Mills (2005) and Lesimple and Hausberger (2014). Each behavioural sequence had to be repeted at least three times and observed at least five times independently of the period of observation (Table 1).

2.1.2. Session 2: Impact of stall architecture on the production of acoustic signals

2.1.2.1. Subjects and housing conditions. This additional study was performed after the discovery of a potential acoustic indicator of positive emotion, in order to test whether the stall architecture could also impact the expression of well-being. The observations were performed by a single experimenter (CR) between May 31st and June 10th 2016, at site 1.

Twenty-three horses living in this same facility, with the same management conditions (2 daily concentrate meals, provided hay once a day, 1 h exercise/day, straw bedded single stalls) all performing dressage, were observed. Horses (6 mares and 17 geldings), aged 6–17 years ($\bar{X}$ ± se = 12.04 ± 0.71), mainly (60.9%) French Saddlebreds (N = 14, for the other breeds: Hannoveraner, N = 4; Anglo-Arabian, N = 3; Rheinisches & Oldenburger, N = 1 each), were observed in the OS and GS stalls (Fig. 1a & b) where they had been housed for more than 6 months (see Table 2.).

2.1.2.2. Data collection. Horses were observed using a scan sampling method (Altman, 1974), for three sessions of 30 min per day outside feeding time (at least 1 h after the meal) leading to 214 ($\bar{X}$ ± se = 214.37 ± 17.7) scans per horse. During these three periods, both vocal and non-vocal acoustic signals were recorded. Since definitions of horses' acoustic repertoire differ somewhat between studies, the terms used follow the descriptions by Kiley (1972), Stomp et al. (2018a) and Waring (2003):

- snore: very short raspy inhalation sound, produced in a mild alert context (*i.e.* investigation of a novel object or obstacle);
- blow: short very intense non-pulsed exhalation through the nostrils, produced in high alert contexts, generally associated with vigilance/alarm postures;
- snort: more or less pulsed sound produced by nostril vibrations while expulsing the air, with a slightly longer duration in comparison to the blow, observed in calm relaxed contexts;
- nicker: modulated low intensity vocal sound produced during in particular at close social contact or food anticipation.
- whinny: loud vocalization produced mostly in response to social separation.

Table 1
List and description of the behaviours observed, during the two studies. STB were identified according to Mills (2005). * Waring (2003), ** Kiley-Worthington (1976).

Behaviours			Description
Calmness / Quietness	Feeding		Eating the straw or hay
	Resting*	*Standing*	Half closed eyes
		Lying	Sternal or Lateral
	Maintenance		Urination, Defecation, Scratching, Rolling, Rubbing
Excitation / Repetitive behaviours	Agitation / Stress Vigilance**		Alarm posture, with fixed immobility, the head held high, ears pointed forwards, sometimes tail raised
	STB	*Weaving*	Lateral movement of the head, neck, forequarters and sometimes hindquarters
		Cribbing	The horse grasps a fixed object with its incisors, and pulls backwards
		Wind sucking	The horse grasps a fixed object with its incisors, pulls backwards and draws air into its oesophagus
		Head shaking	Head movement including head tossing and nodding : Repetitive and sudden vertical movements of the head and neck sometimes involving lateral components (circling)
		Compulsive licking	Repetitive licking of the same object of the environment
		Compulsive biting	Repetitive biting of the same object of the environment
		Tongue movements	Repetitive movements of the tongue inside or outside the mouth

Table 2
Horses' characteristics in the study performed at the ENE (study 1): distribution of the sex, breeds and age. Number and distribution (%) according to the stall architecture: OS = Open Stalls, GS = Grid Stalls.

		Open Stall (OS)		Grid Stall (GS)	
Sex	Gelgings	9	*75%*	8	*72.7%*
	Mares	3	*25%*	3	*27.3%*
Breeds	French Saddlebreds	7	*58.30%*	7	*63.60%*
	Hannoveraner	2	*16.70%*	2	*18.20%18.20%*
	Anglo-Arabian	1	*8.33%*	2	
	Rheinsches	1	*8.33%*	0	*0%*
	Oldenburger	1	*8.33%*	0	*0%*
Age	$\bar{X}$ ± se	11.41 ± 0.99		12.72 ± 1.02	

Stomp et al. (2018b) described two categories of snorts that differed in the degree of pulsation and reflected different levels of positive emotions but given the important background noise in the site 1′s environment (*i.e.* automatic system to remove manure), we could only determine here the presence/absence of snorts.

2.1.3. Statistical analyses

In both session 1 and 2, data were not normally distributed, and the aim was to compare two distinct groups of horses. Thus, the same non-parametric statistical tests for independent data were used on each dataset independently.

To compare the number of horses performing given behaviours or activities between horses housed in Open Stalls and horses housed in Grid Stalls, we used Chi Square tests, classically used in the literature to compare unpaired discreet data (Siegel, 1956). Mann-Whitney U tests (MW U test) were used to compare the frequency of occurrences of behaviours between OS and GS groups (see 2.1). The statistical tests were performed using Statistica® 13.

2.2. Results

2.2.1. Session 1: Behavioural expressions of good/bad welfare

While stall architecture did not seem to affect activities such as eating (OS: $\bar{X}$ ± se = 0.70 ± 0.276; GS: $\bar{X}$ ± se = 0.73 ± 0.268; MW U test: U = 133, p = 0.85) or drinking (OS: $\bar{X}$ ± se = 0.03 ± 0.029; GS: $\bar{X}$ ± se = 0.02 ± 0.028; U = 114, p = 0.60), clear differences appeared for other behaviours. Thus, the time spent in vigilance (alert posture) (OS: $\bar{X}$ ± se = 0.2 ± 0.3; GS: $\bar{X}$ ± se = 0.12 ± 0.02; U = 76.5, p = 0.05) or movements of the head with fixed stares towards the environment (OS: $\bar{X}$ ± se = 0.71 ± 0.08; GS: $\bar{X}$ ± se = 0.46 ± 0.05; U = 68.5, p = 0.03) was higher in the horses in OS (Fig. 2a), while the horses living in GS spent more time sleeping (OS: $\bar{X}$ ± se = 0.02 ± 0.01; GS: $\bar{X}$ ± se = 0.04 ± 0.01;U = 197, p = 0.007) (Fig. 2b).

All horses performed at least one type of STB during the observation period with frequencies of 0.18–2.13 STB per minute ($\bar{X}$ ± se: 0.49 ± 0.07) (Table 3.). Three (9.4%) of them performed one type of STB, six (18.8%) performed two types of STB, ten (31.2%) performed three types of SB/ARB and thirteen (40.6%) performed four or more types of STB. There was overall no difference in the time spent in STBs according to stall architecture (OS: $\bar{X}$ ± se = 0.047 ± 0.046; GS: $\bar{X}$ ± se = 0.037 ± 0.025; U = 116.5, p = 0.692). However, there was a clear difference in the type of STB performed according to the type of stall. Almost half (41.2%) of the OS horses were observed weaving while it was seen in less than 10% of GS horses (Chi² test, N_{OS} = 7/17, N_{GS} = 2/15 p < 0.005) (Fig. 3). On the contrary, repetitive grid licking was performed in about 80% of the GS stall horses and in less than 10% of the OS stall horses (Chi² test, N_{OS} = 2/17, N_{GS} = 11/15 p < 0.001) (Fig. 3). Moreover, the frequency of the different types of STBs expressed differed largely according to stall architecture: the horses living in OS spent more time weaving (OS: $\bar{X}$ ± se = 0.042 ± 0.072; GS: $\bar{X}$ ± se = 0.011 ± 0.0.034; U = 91.5, p = 0.091) and in tongue play (OS: $\bar{X}$ ± se = 0.143 ± 0.142; GS: $\bar{X}$ ± se = 0.054 ± 0.0.054; U = 64, p = 0.017) than the horses living in GS which spent more time repetitively licking the grids (OS: $\bar{X}$ ± se = 0.002 ± 0.006; GS: $\bar{X}$ ± se = 0.087 ± 0.0.102; U = 215, p = 0.0002).

2.2.2. Session 2: acoustic indicators

During the three 30-minutes observation periods, horses produced whinnies, nickers, snorts, but no snores or blows. The analysis of the production of whinnies and nickers showed that neither the number of horses performing the behaviour (Chi² test, N_{OS} = 2/12, N_{GS} = 2/11 p > 0.57 and N_{OS} = 3/12, N_{GS} = 1/11 p > 0.81 respectively) nor the frequency of expression differed between OS and GS horses (Mann-Whitney U test, respectively OS: $\bar{X}$ ± se = 0.12 ± 0.06; GS: $\bar{X}$ ± se = 0.05 ± 0.03, and OS: $\bar{X}$ ± se = 0.21 ± 0.09; GS: $\bar{X}$ ± se = 0.10 ± 0.08, p > 0.1 in both cases).

Interestingly though, when looking at the production of snorts, only 5 out of the 12 OS horses snorted at least once during the observation, whereas all (N = 11) GS horses did (respectively 41. 7% and 100.0%, Chi-square tests, p = 0.002) (Fig. 4). In addition, the frequency of snorting was lower in OS horses (respectively 0.27 and 0.57% of scans, MW U test, p = 0.026).

2.3. Conclusion

Horses that lived in outdoors stalls allowing a visual access to the outside but no close social contact expressed more "excitation" behaviours (vigilance and alert attention), while horses living indoors and having close social (at least visual and nose-to-nose) contacts expressed more quietness (resting) and snorts, potentially indicative of well-being. If all horses displayed STB, confirming that constant single stall housing (amongst other factors) is inappropriate, "more severe" forms (*e.g.* weaving) were predominant in horses with windows on outdoors. These observational studies show thus that the stall architecture has an impact on both the welfare state and the expression of positive emotions after long-term housing (at least 6 months). In the following steps, we tested therefore whether there could be short-term effects on the same behavioural measures, in particular when the access to a large outdoors visual horizon is or not restricted.

3. EXPERIMENT 2: experimental study in broodmares

The aim of the second study was to test the immediate impact of changes in housing conditions (stall architecture with or without large visual horizon) on the behaviour of horses, and especially the frequency and type of stereotypic behaviours.

3.1. Material & methods

3.1.1. Subjects and housing conditions

Forty-two purebred Arabian broodmares, aged 4 to 22 years ($\bar{X}$ ± se = 9.23 ± 0.83), were observed from March 21st to May 26th 2011 in the national breeding facility of Sidi Thabet in Tunisia (located 20 km from Tunis). All mares were under the same management conditions, *i.e.* housed in individual straw bedded stalls (15 m²), with barley grains (4 kg/day) and four kg of hay every evening, released every day from 09:00 a.m. to 03:00 p.m. in groups in a paddock with *ad libitum* access to water and limited shelter (5 trees). No food was available then but some freshly cut grass was left on the ground around 12:00 p.m. every day. None of the mares was pregnant at that time. The 42 mares came from 30 different breeding studs ($\bar{X}$ ± se = 1.36 ± 0, 1 mares/stud), which prevented a potential effect of their management history. They had been in the facility for 1 to 3 weeks before the start of observations. Thus, all the mares were under the same management conditions at the time of the observations.

Two types of stalls were available for housing at night: the Open

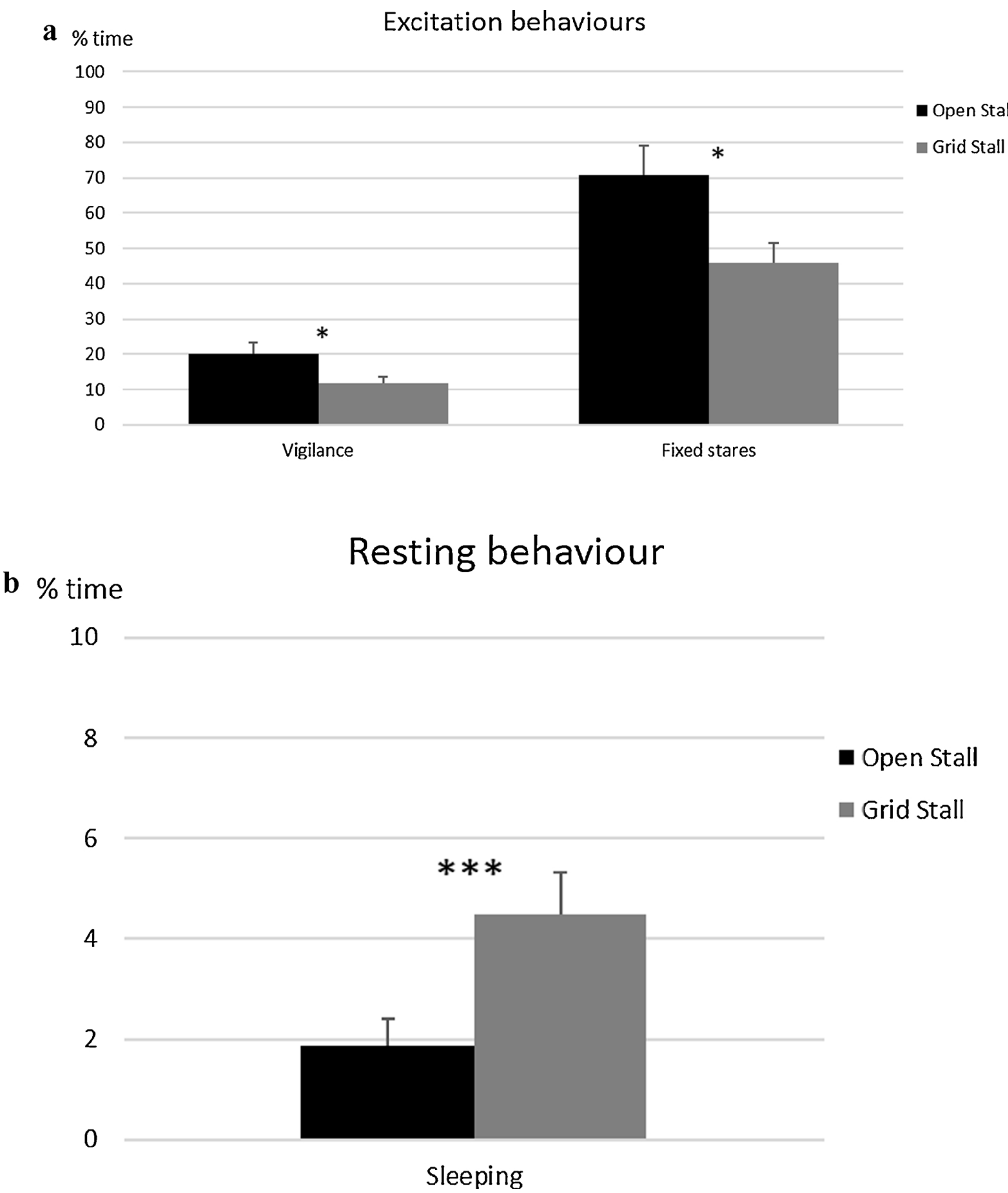

Fig. 2. Impact of the type of stall on (a) the excitation behaviours, (b) resting behaviours performed in Study 1. Mann Whitney U test, *:$p < 0.05$; **:$p < 0.01$.

Table 3
Prevalence and type of STB (number and % of horses) observed and their distribution according to stall architecture in the study at the ENE (study 1). The prevalence of SB/ARB, whatever their type, was higher in horses housed in Open Stalls.

	Total		Open Stall (OS)		Grid Stall (GS)	
	Nb	%	Nb	%	Nb	%
Weaving	9	*28.13*	7	*41.18*	2	*13.33*
Cribbing	4	*12.50*	2	*11.76*	2	*13.33*
Windsucking	4	*12.50*	2	*11.76*	2	*13.33*
Head shaking/tossing	24	*75.00*	12	*70.59*	12	*80.00*
Repetitive tongue movements	31	*96.88*	17	*100.00*	14	*93.33*
Repetitive licking of the wall	15	*46.88*	8	*47.06*	7	*46.67*
Repetitive licking of the grid	13	*40.63*	2	*11.76*	11	*73.33*
Repetitive biting of the grid	14	*43.75*	6	*35.29*	8	*53.33*

Stall (OS, Fig. 5a) with half front door open to the outside and thus the possibility to put the head outside and have a large visual horizon, or the Grid Stall (GS, Fig. 5b) with a grid on the upper part of the front door, preventing the horse of having its head outside and thus leading to a limited visual horizon. For the experiment, every evening, each mare was randomly assigned to one or the other type of stall (*OS*: $\bar{X} \pm se = 51.46 \pm 1.15$ times, GS: $\bar{X} \pm se = 44.44 \pm 1.15$ times). Therefore, the behaviour of the same mares could be compared according to the stall type, the experiment being conducted over a period of 69 days.

3.1.2. *Data collection*

Observations were made by two observers (AK & SB) every day from March 18th to May 26th 2011 (69 days) using instantaneous scan sampling (Altman, 1974). Twice a day (once in the morning and once in the evening after feeding), each observer walked twice along the stalls and noted the behaviour of each of the mares at the instantaneous time of observation. A total of 11684 scans ($\bar{X} \pm se$ 278.2 ± 12.2/mare, range 128–424) was recorded during the 69 days of observation. The time-budget for each behaviour was determined as the recorded

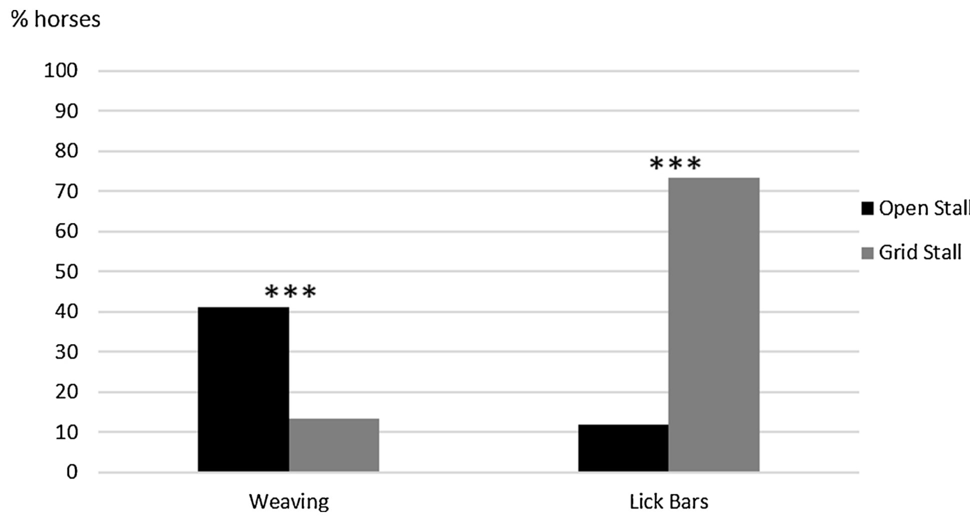

Fig. 3. Expression of different types of SB/ARB according to the type of stall. Chi Square test, ***:$p < 0.005$.

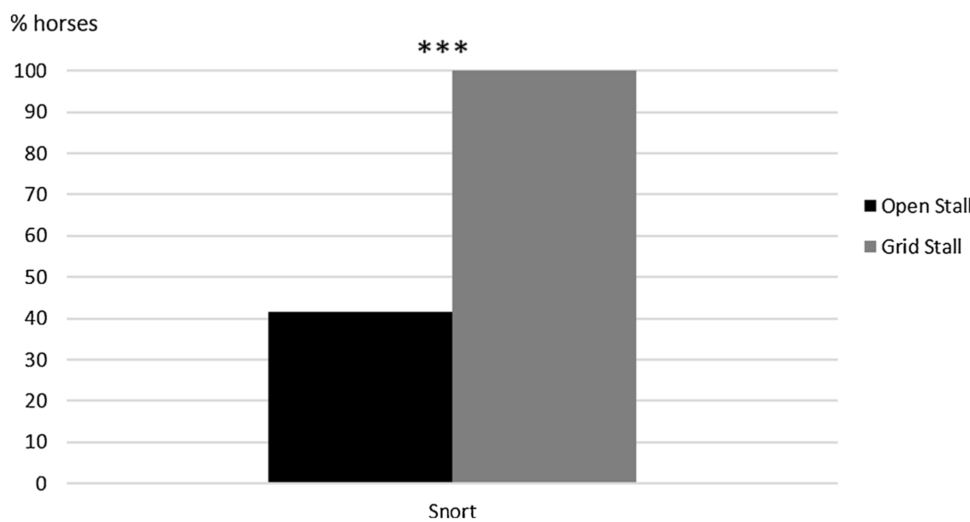

Fig. 4. Proportion of horses performing snorts according to the type of stall in Study 1. All horses in GS snorted. Chi Square test (performed on real numbers), ***:$p < 0.005$.

number of scans of each behaviour divided by the total recorded number of scans for each horse.

3.1.3. Statistical analyses

As the data were not normally distributed, non-parametric statistics were used. The aim here being to compare the behaviour of the same horses placed in two different conditions, statistical tests for paired data were used.

To evaluate the impact of the type of housing (Open Stall and Grid Stall) on the expression of behaviours, we used McNemar tests, particularly adapted to experimental designs where each individual acts as its own control (Siegel, 1956). Wilcoxon were used to compare the frequency of occurrences of behaviours between OS and GS groups (see 2.1). The statistical tests were performed using Statistica® 13.

3.2. Results

The stall architecture did not impact maintenance behaviours such as urination (% of scans, OS: $\bar{X} \pm se = 0.2 \pm 0.0005$, GS: $\bar{X} \pm se = 0.2 \pm 0.0006$, Wilcoxon test, $Z = 0.34$, $p = 0.34$), defecation (% of scans, OS: $\bar{X} \pm se = 0.6 \pm 0.001$, GS: $\bar{X} \pm se = 1.00 \pm 0.002$, $Z = 1.77$, $p = 0.078$) or scratching (% of scans, OS: $\bar{X} \pm se = 0.6 \pm 0.001$, GS: $\bar{X} \pm se = 0.7 \pm 0.001$, $Z = 0.41$, $p = 0.68$), but had an impact both on behaviours reflecting calmness (*i.e.* resting, foraging) or excitation/welfare impairment (*e.g.* STB, vigilance). Thus, when placed in GS (no opening to the outside), the mares spent significantly more time foraging (% of scans, OS: $\bar{X} \pm se = 35 \pm 0.02$, GS: $\bar{X} \pm se = 47 \pm 0.01$, $Z = 5.59$, $p < 0.01$) and resting, whether standing (% of scans, OS: $\bar{X} \pm se = 6.00 \pm 0.005$, GS: $\bar{X} \pm se = 15.00 \pm 0.008$, $Z = 5.38$, $p < 0.01$) or lying (% of scans, OS: $\bar{X} \pm se = 0.0 \pm 0.0$, GS: $\bar{X} \pm se = 0.3 \pm 0.001$, $Z = 2.02$, $p = 0.04$) whereas they expressed more vigilance (alert postures) when they were in OS (% of scans, OS: $\bar{X} \pm se = 26.00 \pm 0.01$, GS: $\bar{X} \pm se = 9.00 \pm 0.007$, $Z = 5.64$, $p < 0.001$) (Fig. 6a).

Thirty-four of the forty-two mares (81%) performed a stereotypic behaviour at least once. Five types of abnormal or stereotypic behaviours (STB) were observed: weaving, cribbing, wind sucking, head tossing/nodding and repetitive pawing (see Table 3). The mares spent six times more time performing stereotypic behaviours, whatever the type of STB, when placed in the OS than in GS (% of scans, OS: $\bar{X} \pm se = 0.07 \pm 0.02$, GS: $\bar{X} \pm se = 0.01 \pm 0.004$, $Z = 3.48$, $p < 0.01$) or when considering only weaving (% of scans, OS: $\bar{X} \pm se = 0.04 \pm 0.02$, GS: $\bar{X} \pm se = 0.007 \pm 0.003$, $Z = 3.41$, $p < 0.01$), cribbing (% of scans, OS: $\bar{X} \pm se = 0.03 \pm 0.007$, GS: $\bar{X} \pm se = 0.006 \pm 0.002$, $Z = 3.51$, $p < 0.01$) and head tossing/nodding (% of scans, OS: $\bar{X} \pm se = 0.002 \pm 0.0007$, GS: $\bar{X} \pm se = 0.0007 \pm 0.0004$, $Z = 2.06$,

Fig. 5. (a) Stall architecture in Study 2 (a) Open Stall (OS), (b) Grid Stall (GS).

$p < 0.01$) (Fig. 6b). Pawing and wind sucking were only performed when in OS, and their prevalence was too small to allow statistical comparisons (see Table 4.). Twenty mares expressed one type of STB, eight expressed two types of STB, five expressed three types of STB and one expressed more than four types of types of STB. The impact of stall architecture on these behaviours was further confirmed when looking at the number of mares performing them. Thus, fifteen mares (35.7%) performed stereotypic behaviours only when in the OS stalls and only two (4.8%) in GS (McNemar test, $p = 0.003$). Overall, mares expressed all types of stereotypic behaviours when in OS, while repetitive pawing and windsucking were not observed in GS (Table 3).

3.3. Conclusion

When placed in stalls allowing them to put their head outside and to access a larger visual horizon, the mares were more agitated (vigilance), while they spent more time in "quiet" activities (resting and foraging) in gridded stalls, preventing them from putting their head outside. Furthermore, the prevalence of STB was much higher in OS and a third of the mares performed STB only when in OS. This experimental study thus shows that even a short-term exposure to inappropriate stall architecture has a strong impact on the expression of welfare alteration.

4. Discussion

The results obtained here confirm the inappropriateness of constant single box housing for horses (*e.g.* Benhajali et al., 2010; Lesimple et al., 2016; Visser et al., 2008), as indicated by the high prevalence of SB/ARB observed. However, they also reveal that, even in such restricted type of housing, some conditions, in particular in regards to the stall architecture, may be less appropriate than others. Thus, we show that both the frequency of occurrence and the type of stereotypies performed seem to be affected by at least two aspects of stall architecture: the presence of lateral grids allowing some social contacts and the presence of grids at the front door preventing the horse to put the head out. First, having close (visual/olfactory/ nose-to-nose) contact with neighbours diminishes the risk of stereotypic behaviours and vigilance while increasing the occurrence of behaviours reflecting quietness and positive emotions (*e.g.* resting, snorts). Second, it appears that changes in housing, *i.e.* stall architecture, induce immediate behavioural changes, with the major but intriguing finding that increasing the visual horizon by allowing horses to put their head outside is an aggravating factor for the production of stereotypic behaviours, and especially weaving considered as reflecting frustration of social contact (Cooper et al., 2000). In addition, it is worth noting that the second site had a lower prevalence of SB/ARB than the first one (where horses have no opportunity to go out for free movement) which may be due to differences in occupation, but overall to the mares being in paddocks half time (Heleski et al., 2002; Lesimple et al., 2016; Waters et al., 2002).

Constant single housing is known to be detrimental for horses at any age (*e.g.* Heleski et al., 2002; Lesimple et al., 2016; Waters et al., 2002) while pair housing may improve the situation (Visser et al., 2008; Benhajali et al., 2010). When given the choice, horses prefer to go to places where there are conspecifics (Lee et al., 2011) and cows prefer a pen with a conspecific picture (compared to brushes or straw bedding) and spend more time ruminating when in presence of the picture than in the other conditions (Ninomiya and Sato, 2009). The importance of close social contact has also been demonstrated by giving a visual access to neighbours through grids (Cooper et al., 2000) or providing "substitutes" such as a horse picture or a mirror (Mills and Davenport, 2002; McAfee et al., 2002; Kay and Hall, 2009). Videos of conspecifics (Shapiro and Bloomsmith, 1995) and the presence of mirrors (Gallup and Suarez, 1991) in single housed rhesus monkeys decrease the production of stress-related behaviours and a picture of a conspecific's face decreases heart rate and adrenaline concentration in sheep (Da Costa et al., 2004). However, the effects are not necessarily long-lasting and it is not always clear what is really perceived through a mirror (Galley & Suarez 1991, Baragli et al., 2017). Therefore, care should be given to give access to a genuine close social contact with a preferred familiar congener, especially as it seems to increase positive emotions as shown here through the increased production of snorts in stalls allowing contact between neighbours (see also Stomp et al., 2018a). Horses, like other species, are ready to work for even partial access to a conspecific (*e.g.* part of a real congener, like head and neck or through a fence or picture of a congener): in Sondergaard et al. (2011)'s study, horses could push a lever up to 191 times in order to have access to a social stimulus while single housed starlings could put their beak up to 297 times per day to obtain each time the broadcast of a conspecific's picture (Perret et al., 2015), showing how high is the motivation of social animals to interact with or at least have a visual access to conspecifics.

However, a rather more intriguing result of the present study is also that increasing the visual horizon, by allowing the horse to put their head outside was related to an increase of indicators of compromised welfare and agitation. Some studies had shown that there were more stereotypic behaviours in horses housed in conventional stalls with the front half door open and a view on the stable courtyard (Cooper et al., 2000; Lesimple et al., 2016). Here we demonstrate that even when there is a small possibility for close social contact, this outdoor view is a source of more agitation and chronic stress-related behaviours (study 1)

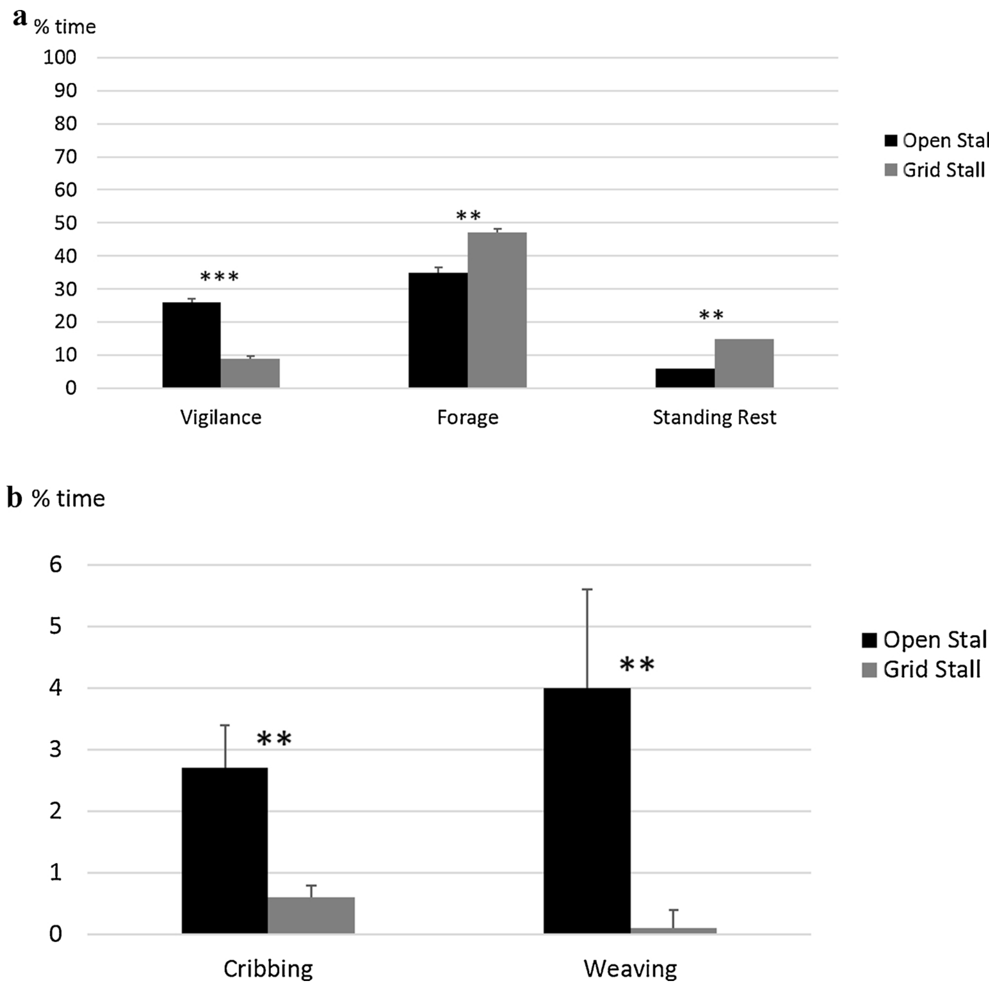

Fig. 6. Impact of the type of stall on the time spent (a) in "quiet" behaviours and vigilance according and (b) in stereotypic / abnormal repetitive behaviour in the Study 2. When placed in GS, mares spent more time in quiet behaviours and less time in vigilance, and 2–4 time less stereotyping. Wilcoxon Test, **:$p < 0.01$; ***:$p < 0.005$.

Table 4
Prevalence (number and % of horses) of the different types of SB/ARB and their distribution according to the stall architecture in Study 2 (broodmares). SB/ARB, whatever their type, were more expressed when horses were in Open Stalls.

	Total		Open Stall (OS)		Grid Stall (GS)	
	Nb	%	Nb	%	Nb	%
Weaving	15	*35.71*	15	*35.71*	8	*19.05*
Cribbing	25	*59.52*	22	*52.38*	13	*30.95*
Windsucking	1	*2.38*	1	*2.38*	0	*0.00*
Head tossing/nodding	11	*26.19*	9	*21.43*	3	*7.14*
Repetitive pawing	4	*9.52*	4	*9.52*	0	*0.00*

and that the effect is immediate (study 2). This is especially remarkable in the broodmare population where this was the only difference between the two types of stalls: mares that had grids on the half door performed less stereotypic behaviours and spent more time foraging and resting, the latter behaviours known to occur more in calm and positive situations (Benhajali et al., 2009; Greening et al., 2013; Kwiatkowska-Stenzel et al., 2016; Greening et al., 2013; Pessoa et al., 2016; Raabygmale and Ladewig, 2005) than those who could have the head outside and watch out-of-reach conspecifics and humans walking around.

Another remarkable result is that the type of stereotypic behaviours performed varied according to stall architecture. Thus, in study 1, weaving was more frequent in the OS while repetitive grid licking predominated in the GS. In study 2, all stereotypic behaviours, whether locomotor or oral, increased when the mares could have their head outside, but some STB, mainly repetitive pawing, head movements and weaving, were particularly impacted. In other species, some types of stereotypic behaviours are supposed to reflect escape attempts such as bar gnawing in rodents (Würbel et al., 1996, 1998) or somersaulting in starlings (Feenders and Bateson, 2012). In starlings, an increase of the visual horizon, by broadcasting videos of landscape, was associated with an increase of somersaulting (Coulon et al., 2014). It has been proposed in horses that weaving may result from social or movement frustration (Mills, 2005). In our studies, it could be argued that weaving is more frequent in OS because the movement is easier with the head above the door. However, the study 2 shows that the mares could also perform it when the door was closed with a grid, thus this cannot be the sole explanation. It is also possible that the repetitive licking of the grids in the indoor horses of study 1 was related to a motivation to be closer to the neighbour.

It has been proposed that STB result from chronic frustration (Ödberg, 1978; Fureix et al., 2011), and it is quite possible that horses experience more frustration with an outdoor view, where they can see large spaces and/or other horses that they cannot reach, or see other horses given access to movement (ex in the riding arena or walking along). Monkeys are more frustrated to watch a conspecific eating an (unreachable) appetitive food than simply being denied access to the same visible food (Brosnan and de Waal, 2003). Thus, open front doors may induce more frustration leading to welfare impairment, due to either being unable to join the distant horses, or being unable to move out of the stall as do the other horses. Besides, the immediate influence of the type of housing on the mares' behaviour in study 2 shows in any case that stereotypic behaviours may be more flexible than often assumed as both their frequency and types could change rapidly for the same individuals as a result of a change in the environment. Finally, former studies conducted on Arabian broodmares in the same facility (site 2) showed that when released in paddocks in groups with congeners, they were never observed stereotyping (Benhajali et al., 2008,2009). In the same way, a recent study conducted in site 1 showed that sport horses that never went to paddock beforehand displayed a very fast decrease of SB/ARB expression in box during a period where they had 1 h daily access to a paddock (Lesimple et al in prep). Thus, changes in management practices may have immediate and durable effects, even on such behaviours.

While constant single stall housing remains inappropriate for horses, housing has effects on horses' chronic stress levels and favouring close social contact, even partial (access to a limited part, *e.g.* head and neck only, or through a fence or window), and less sources of frustration when building such housing systems remains important.

This study underlines once again the importance of animal-based criteria for identifying best practices (*e.g.* Blokhuis et al., 2003) and that "only animals can tell". Humans would tend to think that being able to watch outside and see activities would reduce boredom and hence stereotypies, while obviously this situation creates much more frustration as suggested also by Cooper et al (2000)'s earlier study.

Declaration of Competing Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

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