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

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21

22 ABSTRACT

23

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

43

44 Keywords: stereotypic / abnormal repetitive behaviours, time budget, housing, welfare, horse

45

46 1 - INTRODUCTION

47

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

52 Beyond spatial, hence movement, restriction, this housing is also associated with a lack of social
53 contact, one of the major sources of emergence of stereotypic behaviours in social captive/domestic
54 species (e.g. Mason 1991). Parent-raised parrots, when separated, develop stereotypies when singly
55 housed but not if they are housed in pairs (Meehan et al, 2003). Similarly, Visser et al (2008) found, in
56 young horses stabled for the first time, that 67 % of young warmblood horses housed in single stalls
57 developed stereotypic behaviours in the two first weeks after their first stall housing while pair housed
58 animals did not. Moreover, the singly housed young horses were more agitated (increase of vigilance,
59 neighing, pawing, nibbling) while paired horses spent more time eating. A study on adult mares also
60 showed that broodmares with foals, thus having social interactions, expressed 5 times less stereotypic
61 behaviours than their without-foal neighbours housed in the same conditions (Benhajali et al 2010).
62 Singly housed horses and starlings are ready to “work” to obtain direct (Lee et al 2011), even if partial
63 (Sondergaard et al 2011) or mimicked (picture: Perret et al 2015) social contact. In a variety of species
64 (long tailed macaques: Crockett et al 1994; baboons: Kessel & Brent 2001), the increase of social
65 opportunities also decreases the frequency of STB, even if social opportunities are slight (horses: naso-
66 nasal/visual contact, Cooper et al 2000, Mills & Davenport 2002), or mimicked (horses: mirror: Kay &
67 Hall 2009; Mills & Davenport 2002, conspecific picture: Mills & Riezebos 2005). In horses, this is also
68 associated with a decrease of stress and excitation behaviours (vigilance, active locomotion) and an
69 increase of behaviours reflecting calmness (resting, foraging), even in horses with a long history of
70 stereotypic behaviours (e.g. weaving, Mills & Davenport 2002). It is well admitted that SB/ARB reflect
71 chronic stress in captive and domestic animals (Mason 1991) and hence are reliable indicators of
72 compromised welfare. In horses, the expression of SB/ARB is associated with lowered cognitive
73 abilities (Hausberger et al 2007, Parker et al 2018) and fertility (Benhajali et al 2014). Thus, despite the

74 fact that STB may help horses cope (Fraser et al 1997), their efficiency in terms of coping remains to be
75 demonstrated (e.g. Fureix et al 2013).

76 On the other hand, horses are also ready to work for access to a paddock even if alone as compared
77 to being in a single stall, showing that movement restriction, and especially free movement (no
78 motivation for constrained locomotion) is also a behavioural /physiological need (Lee et al 2011,
79 Gorecka-Bruzda et al 2013). It has been proposed that captive laboratory animals, that experience high
80 levels of spatial restriction, appear to develop motor STB related to flight attempts (mice: Lewis & Hurst
81 2004, Würbel et al 1996, 1998, starlings: Feenders 2012). Similarly in horses, it has been suggested that
82 weaving, a well-known locomotor stereotypic behaviour, would particularly reflect the frustration of not
83 being able to go out of the stall (Mills 2005).

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

101 that changes in the environment may be associated not only in changes in the frequency but also in the
102 types of stereotypic behaviours.

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

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

128 (Stomp et al 2018), we added a short later study on acoustic signals produced according to stall
129 architecture on site 1.

130

131 2 – EXPERIMENT 1: observational study in sport horses

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

136 2.1 – Material & Methods

137 2.1.1 – Session 1: Behavioural observations

138 2.1.1.1. *Subjects and housing conditions*

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

143 Thus, all horses shared the same environmental conditions, were of the same sex and breed with
144 management condition differing only in terms of type of stalls they lived in, while the surfaces of the
145 stalls were similar (9.75 m² for type 1 stalls, 9 m² for type 2 stalls). Open Stalls (OS, N=17 horses)
146 (Fig.1a) had limited openings (3.35 m²) consisting of a small side window (0.49 m²) with grid that
147 allowed horses to see one neighbour and mostly the open front half door (2.86 m²) enabling the horse to
148 have its head outside. This opening gave a view over the outdoor riding arena and horses being led from
149 their stall to the working areas and back. Grid Stalls (GS, N=15 horses) (Fig.1b) were located in an
150 indoor barn with no outdoor openings, but half side walls replaced with grids, enabling sight and nose
151 to nose contact with their two neighbours, as well as a grid above their door, enabling sight of neighbours
152 across the corridor: they could see therefore more than 5 neighbours (1 on each side and 3 in front at
153 least). This constituted a surface of 11.76 m² openings. Thus, OS stalls favoured a vision of the outside
154 world while GS stalls favoured social visual and olfactory (and some tactile) contacts at close range. All
155 horses had been in this same stall for more than 6 months when the study started.

156 2.1.1.2 - Data collection

157 Each horse was observed during 10 to 11 5-minutes sessions distributed in the morning (08:00 to
 158 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
 159 continuous focal sampling method (Altman 1974), yielding 50 to 55 minutes observation per horse
 160 (mean: 54.22 ± 1.84 min/horse). The same observer (EG) recorded all the observations through a voice
 161 recorder while standing outside the stall (see also Fureix et al 2011). This same experimenter had been
 162 performing observations regularly in the previous months, horses were thus habituated to his presence.
 163 The time of observation of a given horse changed every day following a rotation schedule (thus if one
 164 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
 165 05:10 p.m. on day 2, etc). All behaviours were noted (Table 1), and the frequency of observation was
 166 evaluated for each behaviour as the number of occurrences divided per the time of observation (giving
 167 a number of behaviour observed per minute). Stereotypic and abnormal repetitive behaviours (STB)
 168 were identified according to Mills (2005) and Lesimple & Hausberger (2014). Each behavioural
 169 sequence had to be repeted at least three times and observed at least five times independently of the
 170 period of observation (Table 1).

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

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

173

174

175 2.1.2 – Session 2: Impact of stall architecture on the production of acoustic signals

176 2.1.2.1. Subjects and housing conditions

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

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

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

		Open Stall (OS)		Grid Stall (GS)	
Sex	Geldings	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%
	Anglo-Arabian	1	8.33%	2	18.20%
	Rheinsches	1	8.33%	0	0%
	Oldenburger	1	8.33%	0	0%
Age	$\bar{X} \pm se$	11.41±0.99		12.72±1.02	

189

190 2.1.2.2 - Data collection

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

196 - snore: very short raspy inhalation sound, produced in a mild alert context (*i.e.* investigation of a novel
197 object or obstacle);

198 -blow: short very intense non-pulsed exhalation through the nostrils, produced in high alert contexts,
199 generally associated with vigilance/alarm postures;

200 - snort: more or less pulsed sound produced by nostril vibrations while expulsing the air, with a slightly
201 longer duration in comparison to the blow, observed in calm relaxed contexts;

202 -nicker: modulated low intensity vocal sound produced during in particular at close social contact or
203 food anticipation.

204 -whinny: loud vocalization produced mostly in response to social separation.

205 Stomp et al (2010b) described two categories of snorts that differed in the degree of pulsation and
206 reflected different levels of positive emotions but given the important background noise in the site 1's
207 environment (*i.e.* automatic system to remove manure), we could only determine here the
208 presence/absence of snorts.

209

210 2.1.3 – Statistical analyses

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

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

219

220 2.2 - Results

221 2.2.1- Session 1: Behavioural expressions of good/bad welfare

222 While stall architecture did not seem to affect activities such as eating (OS: $\bar{X}_{\pm se}=0.70 \pm 0.276$; GS:
223 $\bar{X}_{\pm se}=0.73 \pm 0.268$; MW U test: $U=133$, $p=0.85$) or drinking (OS: $\bar{X}_{\pm se}=0.03 \pm 0.029$; GS:
224 $\bar{X}_{\pm se}=0.02 \pm 0.028$; $U=114$, $p=0.60$), clear differences appeared for other behaviours. Thus, the time
225 spent in vigilance (alert posture) (OS: $\bar{X}_{\pm se}=0.2 \pm 0.3$; GS: $\bar{X}_{\pm se}=0.12 \pm 0.02$; $U=76.5$, $p=0.05$) or

226 movements of the head with fixed stares towards the environment (OS: $\bar{X}_{\pm se}=0.71\pm 0.08$; GS:
 227 $\bar{X}_{\pm se}=0.46\pm 0.05$; U=68.5, p=0.03) was higher in the horses in OS (Fig.2a), while the horses living in
 228 GS spent more time sleeping (OS: $\bar{X}_{\pm se}=0.02\pm 0.01$; GS: $\bar{X}_{\pm se}=0.04\pm 0.01$; U=197, p=0.007) (Fig.2b).
 229 All horses performed at least one type of STB during the observation period with frequencies of 0.18 to
 230 2.13 STB per minute ($\bar{X}_{\pm se}$: 0.49 \pm 0.07) (Table 3.). Three (9.4%) of them performed one type of STB,
 231 six (18.8%) performed two types of STB, ten (31.2%) performed three types of SB/ARB and thirteen
 232 (40.6%) performed four or more types of STB. There was overall no difference in the time spent in
 233 STBs according to stall architecture (OS: $\bar{X}_{\pm se}=0.047\pm 0.046$; GS: $\bar{X}_{\pm se}=0.037\pm 0.025$; U=116.5,
 234 p=0.692). However, there was a clear difference in the type of STB performed according to the type of
 235 stall. Almost half (41.2%) of the OS horses were observed weaving while it was seen in less than 10%
 236 of GS horses (Chi² test, N_{OS}=7/17, N_{GS}=2/15 p<0.005) (Fig.3). On the contrary, repetitive grid licking
 237 was performed in about 80 % of the GS stall horses and in less than 10% of the OS stall horses (Chi²
 238 test, N_{OS}=2/17, N_{GS}=11/15 p<0.001) (Fig.3). Moreover, the frequency of the different types of STBs
 239 expressed differed largely according to stall architecture: the horses living in OS spent more time
 240 weaving (OS: $\bar{X}_{\pm se}=0.042\pm 0.072$; GS: $\bar{X}_{\pm se}=0.011\pm 0.034$; U=91.5, p=0.091) and in tongue play (OS:
 241 $\bar{X}_{\pm se}=0.143\pm 0.142$; GS: $\bar{X}_{\pm se}=0.054\pm 0.054$; U=64, p=0.017) than the horses living in GS which spent
 242 more time repetitively licking the grids (OS: $\bar{X}_{\pm se}=0.002\pm 0.006$; GS: $\bar{X}_{\pm se}=0.087\pm 0.0.102$; U=215,
 243 p=0.0002).

244 Table 3. Prevalence and type of STB (number and % of horses) observed and their distribution according to stall
 245 architecture in the study at the ENE (study 1). The prevalence of SB/ARB, whatever their type, was higher in
 246 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

247

248 2.2.2 – Session 2: Acoustic indicators

249 During the three 30-minutes observation periods, horses produced whinnies, nickers, snorts, but no
250 snores or blows. The analysis of the production of whinnies and nickers showed that neither the number
251 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
252 p>0.81 respectively) nor the frequency of expression differed between OS and GS horses (Mann-
253 Whitney U test, respectively OS: $\bar{X} \pm se = 0.12 \pm 0.06$; GS: $\bar{X} \pm se = 0.05 \pm 0.03$, and OS: $\bar{X} \pm se = 0.21 \pm 0.09$; GS:
254 $\bar{X} \pm se = 0.10 \pm 0.08$, p>0.1 in both cases).

255 Interestingly though, when looking at the production of snorts, only 5 out of the 12 OS horses snorted
256 at least once during the observation, whereas all (N=11) GS horses did (respectively 41.7% and 100.0%,
257 Chi-square tests, p=0.002) (Fig.4). In addition, the frequency of snorting was lower in OS horses
258 (respectively 0.27 and 0.57 % of scans, MW U test, p=0.026).

259

260 2.3 - Conclusion

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

271

272 3- EXPERIMENT 2: experimental study in broodmares

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

276 3.1- Material & Methods

277 3.1.1 - Subjects and housing conditions

278 Forty-two purebred Arabian broodmares, aged 4 to 22 years ($\bar{X} \pm se = 9.23 \pm 0.83$), were observed from
279 March 21st to May 26th 2011 in the national breeding facility of Sidi Thabet in Tunisia (located 20km
280 from Tunis). All mares were under the same management conditions, *i.e.* housed in individual straw
281 bedded stalls (15m²), with barley grains (4 kg/day) and four kg of hay every evening, released every day
282 from 09:00 a.m. to 03:00 p.m. in groups in a paddock with *ad libitum* access to water and limited shelter
283 (5 trees). No food was available then but some freshly cut grass was left on the ground around 12:00
284 p.m. every day. None of the mares was pregnant at that time. The 42 mares came from 30 different
285 breeding studs ($\bar{X} \pm se = 1.36 \pm 0$, 1 mares/stud), which prevented a potential effect of their management
286 history. They had been in the facility for 1 to 3 weeks before the start of observations. Thus, all the
287 mares were under the same management conditions at the time of the observations.

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

295

296 3.1.2 - Data collection

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

304

305 3.1.3- Statistical analyses

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

309 To evaluate the impact of the type of housing (Open Stall and Grid Stall) on the expression of
310 behaviours, we used McNemar tests, particularly adapted to experimental designs where each individual
311 acts as its own control (Siegel 1956). Wilcoxon were used to compare the frequency of occurrences of
312 behaviours between OS and GS groups (see 2.1). The statistical tests were performed using Statistica®
313 13.

314

315 3.2- Results

316 The stall architecture did not impact maintenance behaviours such as urination (% of scans,
317 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,
318 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:
319 $\bar{X} \pm se = 0.6 \pm 0.001$, GS: $\bar{X} \pm se = 0.7 \pm 0.001$, $Z = 0.41$, $p = 0.68$), but had an impact both on behaviours
320 reflecting calmness (i.e. resting, foraging) or excitation/welfare impairment (e.g. STB, vigilance). Thus,
321 when placed in GS (no opening to the outside), the mares spent significantly more time foraging (% of
322 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
323 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:
324 $\bar{X} \pm se = 0.0 \pm 0.0$, GS: $\bar{X} \pm se = 0.3 \pm 0.001$, $Z = 2.02$, $p = 0.04$) whereas they expressed more vigilance (alert
325 postures) when they were in OS (% of scans, OS: $\bar{X} \pm se = 26.00 \pm 0.01$, GS: $\bar{X} \pm se = 9.00 \pm 0.007$, $Z = 5.64$,
326 $p < 0.001$) (Fig.6a).

327 Thirty-four of the forty-two mares (81%) performed a stereotypic behaviour at least once. Five types of
328 abnormal or stereotypic behaviours (STB) were observed: weaving, cribbing, wind sucking, head
329 tossing/nodding and repetitive pawing (see Table 3). The mares spent six times more time performing
330 stereotypic behaviours, whatever the type of STB, when placed in the OS than in GS (% of scans, OS:
331 $\bar{X} \pm se = 0.07 \pm 0.02$, GS: $\bar{X} \pm se = 0.01 \pm 0.004$, $Z = 3.48$, $p < 0.01$) or when considering only weaving (% of

332 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:
 333 $\bar{X} \pm se = 0.03 \pm 0.007$, GS: $\bar{X} \pm se = 0.006 \pm 0.002$, $Z = 3.51$, $p < 0.01$) and head tossing/nodding (% of scans, OS:
 334 $\bar{X} \pm se = 0.002 \pm 0.0007$, GS: $\bar{X} \pm se = 0.0007 \pm 0.0004$, $Z = 2.06$, $p < 0.01$) (Fig.6b). Pawing and wind sucking
 335 were only performed when in OS, and their prevalence was too small to allow statistical comparisons
 336 (see Table 4.). Twenty mares expressed one type of STB, eight expressed two types of STB, five
 337 expressed three types of STB and one expressed more than four types of types of STB. The impact of
 338 stall architecture on these behaviours was further confirmed when looking at the number of mares
 339 performing them. Thus, fifteen mares (35.7%) performed stereotypic behaviours only when in the OS
 340 stalls and only two (4.8%) in GS (McNemar test, $p = 0.003$). Overall, mares expressed all types of
 341 stereotypic behaviours when in OS, while repetitive pawing and windsucking were not observed in GS
 342 (Table 3).

343 Table 3. Prevalence (number and % of horses) of the different types of SB/ARB and their distribution
 344 according to the stall architecture in Study 2 (broodmares). SB/ARB, whatever their type, were more
 345 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

346

347 Conclusion

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

354

355 4 - DISCUSSION

356 The results obtained here confirm the inappropriateness of constant single box housing for horses
357 (*e.g.* Benhajali et al 2010, Lesimple et al 2016, Visser et al 2008), as indicated by the high prevalence
358 of SB/ARB observed. However, they also reveal that, even in such restricted type of housing, some
359 conditions, in particular in regards to the stall architecture, may be less appropriate than others. Thus,
360 we show that both the frequency of occurrence and the type of stereotypies performed seem to be
361 affected by at least two aspects of stall architecture: the presence of lateral grids allowing some social
362 contacts and the presence of grids at the front door preventing the horse to put the head out. First, having
363 close (visual/olfactory/ nose-to-nose) contact with neighbours diminishes the risk of stereotypic
364 behaviours and vigilance while increasing the occurrence of behaviours reflecting quietness and positive
365 emotions (*e.g.* resting, snorts). Second, it appears that changes in housing, *i.e.* stall architecture, induce
366 immediate behavioural changes, with the major but intriguing finding that increasing the visual horizon
367 by allowing horses to put their head outside is an aggravating factor for the production of stereotypic
368 behaviours, and especially weaving considered as reflecting frustration of social contact (Cooper et al.,
369 2000). In addition, it is worth noting that the second site had a lower prevalence of SB/ARB than the
370 first one (where horses have no opportunity to go out for free movement) which may be due to
371 differences in occupation, but overall to the mares being in paddocks half time (Heleski et al 2002;
372 Lesimple et al 2016; Waters et al 2002).

373 Constant single housing is known to be detrimental for horses at any age (*e.g.* Heleski et al 2002;
374 Lesimple et al 2016; Waters et al 2002) while pair housing may improve the situation (Visser et al 2008,
375 Benhajali et al 2010). When given the choice, horses prefer to go to places where there are conspecifics
376 (Lee et al 2011) and cows prefer a pen with a conspecific picture (compared to brushes or straw bedding)
377 and spend more time ruminating when in presence of the picture than in the other conditions (Ninomiya
378 & Sato 2009). The importance of close social contact has also been demonstrated by giving a visual
379 access to neighbours through grids (Cooper et al 2000) or providing “substitutes” such as a horse picture
380 or a mirror (Mills & Davenport 2002, McAfee et al 2002, Kay & Hall 2009). Videos of conspecifics
381 (Shapiro & Bloomsmith 1995) and the presence of mirrors (Gallup & Suarez 1991) in single housed
382 rhesus monkeys decrease the production of stress-related behaviours and a picture of a conspecific’s
383 face decreases heart rate and adrenaline concentration in sheep (Da Costa et al 2004). However, the

384 effects are not necessarily long-lasting and it is not always clear what is really perceived through a mirror
385 (Galley & Suarez 1991, Baragli et al 2017). Therefore, care should be given to give access to a genuine
386 close social contact with a preferred familiar congener, especially as it seems to increase positive
387 emotions as shown here through the increased production of snorts in stalls allowing contact between
388 neighbours (see also Stomp et al 2018a). Horses, like other species, are ready to work for even partial
389 access to a conspecific (e.g. part of a real congener, like head and neck or through a fence or picture of
390 a congener): in Sondergaard et al (2011)'s study, horses could push a lever up to 191 times in order to
391 have access to a social stimulus while single housed starlings could put their beak up to 297 times per
392 day to obtain each time the broadcast of a conspecific's picture (Perret et al 2015), showing how high is
393 the motivation of social animals to interact with or at least have a visual access to conspecifics.

394 However, a rather more intriguing result of the present study is also that increasing the visual horizon,
395 by allowing the horse to put their head outside was related to an increase of indicators of compromised
396 welfare and agitation. Some studies had shown that there were more stereotypic behaviours in horses
397 housed in conventional stalls with the front half door open and a view on the stable courtyard (Cooper
398 2000, Lesimple et al 2016). Here we demonstrate that even when there is a small possibility for close
399 social contact, this outdoor view is a source of more agitation and chronic stress-related behaviours
400 (study 1) and that the effect is immediate (study 2). This is especially remarkable in the broodmare
401 population where this was the only difference between the two types of stalls: mares that had grids on
402 the half door performed less stereotypic behaviours and spent more time foraging and resting, the latter
403 behaviours known to occur more in calm and positive situations (Benhajali et al 2009, Greening et al
404 2013, Kwiatkowska-Stenzel et al 2016, Greening et al 2013, Pessoa et al 2016, Raabygmale et al 2005)
405 than those who could have the head outside and watch out-of-reach conspecifics and humans walking
406 around.

407 Another remarkable result is that the type of stereotypic behaviours performed varied according to
408 stall architecture. Thus, in study 1, weaving was more frequent in the OS while repetitive grid licking
409 predominated in the GS. In study 2, all stereotypic behaviours, whether locomotor or oral, increased
410 when the mares could have their head outside, but some STB, mainly repetitive pawing, head
411 movements and weaving, were particularly impacted. In other species, some types of stereotypic

412 behaviours are supposed to reflect escape attempts such as bar gnawing in rodents (Würbel et al 1996,
413 1998) or somersaulting in starlings (Feenders et al 2012). In starlings, an increase of the visual horizon,
414 by broadcasting videos of landscape, was associated with an increase of somersaulting (Coulon et al
415 2014). It has been proposed in horses that weaving may result from social or movement frustration
416 (Mills 2005). In our studies, it could be argued that weaving is more frequent in OS because the
417 movement is easier with the head above the door. However, the study 2 shows that the mares could also
418 perform it when the door was closed with a grid, thus this cannot be the sole explanation. It is also
419 possible that the repetitive licking of the grids in the indoor horses of study 1 was related to a motivation
420 to be closer to the neighbour.

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

437 While constant single stall housing remains inappropriate for horses, housing has effects on horses'
438 chronic stress levels and favouring close social contact, even partial (access to a limited part, *e.g.* head

439 and neck only, or through a fence or window), and less sources of frustration when building such housing
440 systems remains important.

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

446

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453

454

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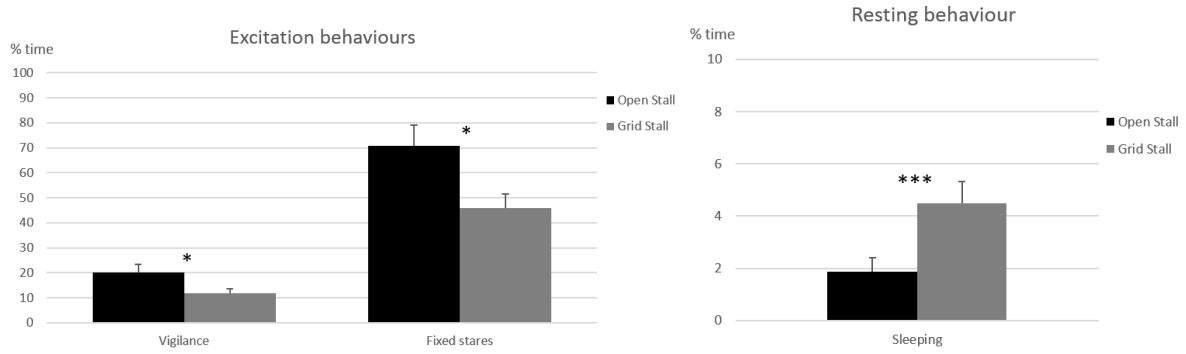
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603 7 – Figures



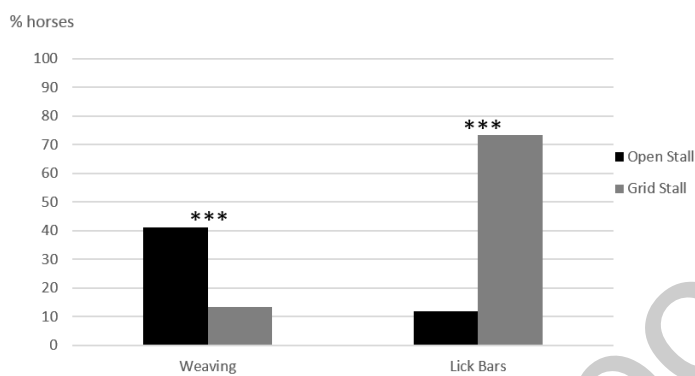
604
605 Figure 1: Stall architecture in Study 1 (a) Open Stall (OS), (b) Grid Stall (GS)



606

607 Figure 2: Impact of the type of stall on (a) the excitation behaviours, (b) resting behaviours performed

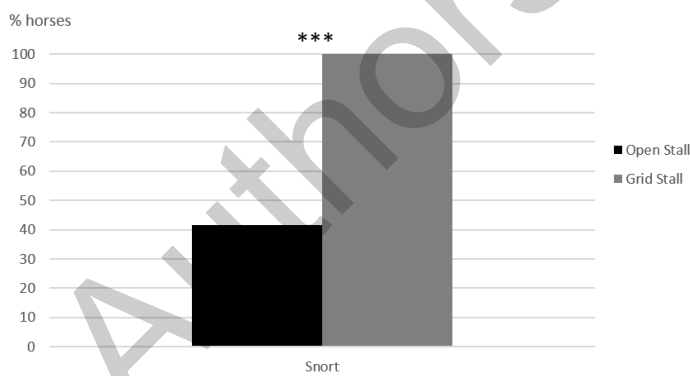
608 in Study 1. Mann Whitney U test, *:p<0.05; **:p<0.01



609

610 Figure 3: Expression of different types of SB/ARB according to the type of stall. Chi Square test,

611 ***:p<0.005



612

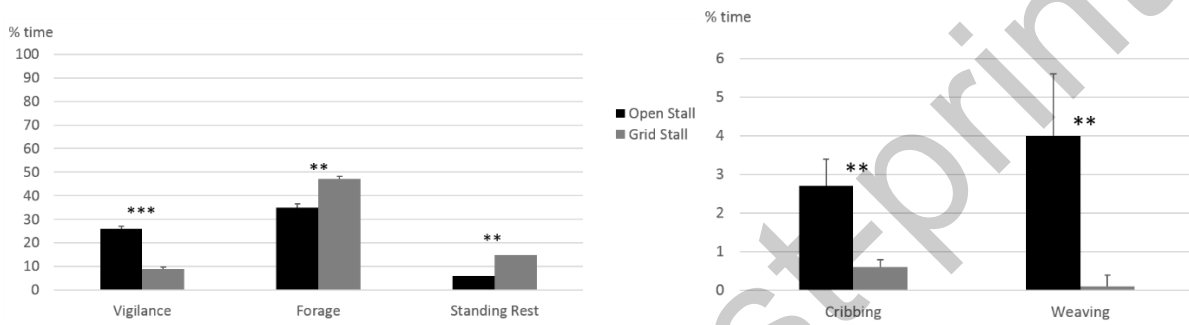
613 Figure 4: Proportion of horses performing snorts according to the type of stall in Study 1. All horses in

614 GS snorted. Chi Square test (performed on real numbers), ***:p<0.005



615

616 Figure 5a: Stall architecture in Study 2 (a) Open Stall (OS), (b) Grid Stall (GS)



617

618 Figure 6: Impact of the type of stall on the time spent (a) in “quiet” behaviours and vigilance according
 619 and (b) in stereotypic / abnormal repetitive behaviour in the Study 2. When placed in GS, mares spent
 620 more time in quiet behaviours and less time in vigilance, and 2 to 4 time less stereotyping. Wilcoxon
 621 Test, **:p<0.01; ***:p<0.005

622

623