Abstract: Every animal species has particular environmental requirements that are essential for its welfare, and when these so-called “basic needs” are not fulfilled, the animals suffer. The basic needs of horses have been claimed to be social contact, social companionship, free movement and access to roughage. To assess whether horses suffer when one or more of the four proposed basic needs are restricted, we examined several studies (n = 38) that reported behavioural and physiological reactions to these restrictions. We assigned the studies according to the four types of responses investigated: (a) Stress (e.g., increased stress hormones), (b) Active (e.g., increased aggression), (c) Passive (e.g., depressive-like behaviour) and (d) Abnormal Behaviour (e.g., stereotypies), and analysed the frequencies with which the investigated responses were shown. Overall, the studies reported that horses did react to restrictions in the described basic needs, especially to combinations of restricted social contact, free movement and access to roughage. The observation of passive responses and the development of abnormal behaviour provided compelling evidence that horses were suffering under these restrictions, and existing abnormal behaviours indicated that they had suffered at some time in the past. We conclude that the literature supports the claim that social contact, free movement and access to roughage are basic needs in horses and need to be taken into consideration to ensure their mental and physical welfare in management and training.

Keywords: abnormal behaviour; active responses; horse; movement; passive responses; roughage; stress; social contact
1. Introduction

Every animal species has particular environmental requirements that are essential for its welfare [1–3] and these are described as basic needs. As a general assumption, it has been claimed that social contact, social companionship, free movement and access to roughage are horses’ basic needs [4–10]. Horses are said to need social contact because in a natural setting they live in large groups, with about 200–400 horses comprising a herd. These herds are divided into subgroups of harems (usually composed of one to five males, several females and their offspring) and bachelor bands (composed of males of different ages) [4,5,7,9,10]. Furthermore, horses are assumed to need social companionship because about one third of all horses form stable social bonds with members of their subgroup. Bonded animals mutually protect each other and their offspring, as well as protecting resources such as food, water and resting places [4,5,9]. In addition, it has been claimed that horses need free movement because under natural conditions, they cover between 3 to 30 km daily [4,6–8]. Finally, horses have been said to need access to roughage as, in nature, they feed on grass for 12 to 16 h per day [4,5,7,8].

However, it must be evaluated whether keeping horses under human management conditions that restrict their basic needs compromises welfare. Therefore, several studies have set out to assess whether horses suffer and, if so, which responses demonstrate suffering, when one or more of these needs are not fulfilled.

Many of these studies analysed whether horses reacted to such restrictions with metabolic [11–14], physiological [15–26], behavioural and/or cognitive [10,25–32] signs of stress [11–25] that would indicate reduced welfare [27]. Horses may, for example, develop gastric ulcers caused by physiological stress and when access to roughage is restricted and gastric acidosis cannot be buffered by the feed and saliva amylase secreted during feeding [27]. Stress under restricted management conditions may also affect the animals’ emotional state and preferences for processing information in one or other brain hemisphere. [25,28–32]. Marr et al. [25], found that left shifts in horses’ motor and sensory laterality were useful behavioural indicators of changes in information processing in particular brain hemispheres when horses experienced stress from a change from group management to individual housing with initial training. Pioneering comparisons between hemispheric electroencephalogram (EEG) wave patterns in horses and those typical of emotional arousal in humans provide further evidence that horses respond negatively to restrictions in movement and social contact [26]. Furthermore, Löckener et al. [10] found that horses develop positive expectations towards their environment, i.e., a positive cognitive bias, when moved to group housing after experiencing management restriction.

Increased displays of certain behaviours in response to restrictions in basic needs have also been evaluated. Horses may show increased aggressive behaviour towards each other [18,22,33,34] and/or towards people [26,35], especially when their social relationships are disrupted [11,18,36–38]. Horses may show more interest in novel objects [38–40] and increased cooperativeness during training (i.e., trainability) when they are stabled in social groups rather than individually [13,21]. They may seek close proximity to their conspecifics more frequently when their social companionship is disrupted, as has been evaluated by applying nearest neighbour analysis [36]. Furthermore, horses may become more active when free movement, either individually or in social groups, is restricted [14,15,19,21,24,38,39], or when foals are weaned and separated from dams and social companions [40]. They may also show more hurried eating behaviour when roughage is limited [14]. On the other hand, horses may respond to restrictions in basic needs by reducing certain behaviour displays [11,15,18–22,24,26,35,38–43] and may even show depressive-type symptoms [22].

Behavioural disorders have also been assessed in horses [17,44], including stereotypies [8,26,45–48] and self-harming (i.e., redirected behaviour [8]). It has been debated whether abnormal behaviour is actually harmful or is rather a behavioural adaptation to a poor environment [47]. In this respect, most authors agree that stereotypies can be considered maladaptive behaviour indicating that horses are suffering under their housing or training conditions, and they give various reasons for this conclusion. Firstly, horses
develop stereotypies in housing in which movement is reduced and there is little social contact. Secondly, free ranging, feral horses have never, to date, been observed showing stereotypic behaviour [7]. Thirdly, animals that displayed redirected behaviour and stereotypies also showed clinical signs of reduced welfare. These included: (a) self-inflicted skin lesions as a result of redirected behaviours, (b) gut damage, including lesions, ulceration and damaged mucosal tissue as a consequence of a wind-sucking and crib-biting [27,49] and (c) increased frequency of laminitis as a result of stereotypic movements such as weaving and box walking [27].

This literature review aims to provide an overview of studies that have evaluated the effects of changes in factors relating to horses’ environmental requirements (specifically social contact, social companionship, free movement, and access to roughage) on behavioural or physiological parameters (Table 1). We asked (a) whether a meta-analysis of the relevant literature supports the claim that social contact, social companionship, free movement and unlimited access to roughage are basic needs in horses, and (b) whether certain measurements can be considered reliable indicators for the analysis of animal welfare and basic need restrictions.

Table 1. Literature on restrictions in “proposed basic needs” in horses. Background colours indicate studies on the restricted basic needs: grey = no restriction, light orange = social contact, light blue = social companionship, light yellow = movement, dark grey = feed, orange = social contact and feed, green = movement and social contact, yellow = movement, social contact and feed. The columns list the test condition or changes in test conditions, the response measurements and the horses’ responses that were observed. For detailed information on the horses and their management conditions please see Supplementary Materials (Table S1).

| Reference            | Restriction          | Condition(s) Observed | Measurements                                      | Response(s)                                                                                       |
|----------------------|----------------------|-----------------------|--------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Hoffmann et al. 2012 | No restriction       | Group housing-no other conditions | Body condition score, Behaviour: aggression, Behaviour: social hierarchy, Behaviour: synchronisation | Good Low Stable Good                                                                                      |
| Christensen et al. 2002 | Social contact | Behaviour of young horses that had either been raised in group housing or single boxes were compared with behaviour when the horses were put out to pasture with other horses of the same age | Nearest neighbour, Behaviour: aggression, Behaviour: agonistic encounters (action and retreat response), Behaviour: social grooming, Behaviour: play | Horses from group housing sought proximity to former stable mates Higher in previously singly housed horses More subtle encounters in previously group housed horses More frequent in previously singly housed horses More frequent in previously singly housed horses |
| Cooper et al. 2000   | Social contact       | Comparison between different types of single box housing: F: front top-half of the door open with a view of the stable courtyard FB: front half-door open and a similar half-door open at the back of the stable with a view to the surrounding fields B: back open only FS: front and one-side panel open with a view into the adjacent stable ALL 4: front, back and both sides open | Stereotypies: weaving, Stereotypies: repetitive nodding | Most common prior to feeding in the morning and prior to putting out to pasture in the afternoon. Less weaving in the FS and ALL4 designs than the F design FB, B, FS and ALL4: less nodding than in the F treatment |
Table 1. Cont.

| Reference                  | Restriction          | Condition(s) Observed                                                                 | Measurements                                      | Response(s)                                                                 |
|----------------------------|----------------------|--------------------------------------------------------------------------------------|--------------------------------------------------|------------------------------------------------------------------------------|
| Hartmann 2010 [18]         | Social contact       | 5 min social isolation from group housing (individually or in pairs)                 | Heart rate                                      | No change                                                                    |
|                            |                      |                                                                                      | Behaviour: towards humans                        | No change                                                                    |
|                            |                      |                                                                                      | Stress                                           | Higher levels of stress in barn weaned foals                                  |
| Nicol et al. 2005 [40]     | Social contact       | Comparison between barn and paddock weaned foals                                      | Behaviour: agonistic with contact                | More in unstable groups                                                     |
|                            |                      |                                                                                      | Behaviour: agonistic                             | More in unstable groups                                                     |
|                            |                      |                                                                                      | Behaviour: greeting                              | More in unstable groups                                                     |
|                            |                      |                                                                                      | Behaviour: play                                  | More variable in unstable groups                                             |
|                            |                      |                                                                                      | Behaviour: agonistic (further behaviours)        | No difference between housing groups                                         |
|                            |                      |                                                                                      | Behaviour: affiliative (further behaviours)      |                                                                              |
| Christensen et al. 2011 [50]| Social companionship| Comparison between housing in unstable (changing) groups and stable (constant) groups|                                                                                      |                                                                              |
| Chaplin and Gretgrix 2010  | Movement             | Same horses compared under Fully stabled (FS), Partially stabled (PS), Yard (Y), and Paddock (P) | Activity: time spent active                      | More active on release from FS and PS housing                                 |
|                            |                      |                                                                                      | Activity: time spent lying down                  | No change                                                                    |
|                            |                      |                                                                                      | Behaviour: aggressive                            | Decreased with increasing size of group paddock                              |
|                            |                      |                                                                                      | Behaviour: submissive                            | Decreased with increasing size of group paddock                              |
|                            |                      |                                                                                      | Stress: faecal glucocorticoids                   | Decreased after movement                                                     |
|                            |                      |                                                                                      | Stress: heart rate variability                   | Decrease of sympathetic activity after movement                              |
|                            |                      |                                                                                      | Activity: movement                               | Increased                                                                    |
|                            |                      |                                                                                      | Stereotypic behaviour                            | Increased with time spent in individual boxes                                |
| McGreevy et al. 1995a [45] | Movement             | Length of time spent in single box housing                                           | Body condition score                             | Decreased                                                                    |
|                            |                      |                                                                                      | Total bilirubin                                  | Increased                                                                    |
|                            |                      |                                                                                      | NEFA                                             | Increased                                                                    |
|                            |                      |                                                                                      | Total bilirubin and beta-hydroxybutyrate         | Higher in males than in females                                             |
|                            |                      |                                                                                      | Thyroxine concentrations                         | No change                                                                    |
| Brinkmann et al. 2013 [51] | Feed                 | Feed restriction                                                                     | Body condition score                             |                                                                              |
|                            |                      |                                                                                      | Total bilirubin                                  | Reduced in winter                                                            |
|                            |                      |                                                                                      | NEFA                                             | Reduced in winter                                                            |
|                            |                      |                                                                                      | Total bilirubin and beta-hydroxybutyrate         | Reduced in winter                                                            |
|                            |                      |                                                                                      | Thyroxine concentrations                         | Reduced in winter                                                            |
|                            |                      |                                                                                      | No change                                       |                                                                              |
| Brinkmann et al. 2014 [52] | Feed                 | Metabolic adaptation to environmental conditions, comparing different quantities of feed and summer and winter temperatures | Body condition score                             | Reduced in winter                                                            |
|                            |                      |                                                                                      | Body mass                                        | Reduced in winter                                                            |
|                            |                      |                                                                                      | Resting heart rate                               | Reduced in winter                                                            |
|                            |                      |                                                                                      | Metabolic rate                                   | Reduced in winter                                                            |
|                            |                      |                                                                                      | Nocturnal hypothermia                            | Increased                                                                    |
| McGreevy et al. 1995b [46] | Feed                 | Stabled without straw bedding and with less feed than 6.8 kg forage/day              | Abnormal behaviour                               | Increased                                                                    |
|                            |                      |                                                                                      | Behaviour: passive                               | Increased when turned out singly                                              |
|                            |                      |                                                                                      | Behaviour: passive                               | Reduced when fed with roughage or grass                                       |
|                            |                      |                                                                                      | Behaviour: item exploration                      | No difference                                                                |
| Jørgensen et al. 2011 [42] | Social contact & feed| Single turnout on paddocks versus group turnout. Feeding grass and roughage           | Body condition score                             |                                                                              |
|                            |                      |                                                                                      | Body mass                                        |                                                                              |
|                            |                      |                                                                                      | Resting heart rate                               |                                                                              |
|                            |                      |                                                                                      | Metabolic rate                                   |                                                                              |
|                            |                      |                                                                                      | Nocturnal hypothermia                            |                                                                              |
| Aurich et al. 2015 [23]    | Movement & social contact | Group versus individual housing                                        | Stress: salivary cortisol                        | No significant difference                                                   |
Table 1. Cont.

| Reference                          | Restriction                          | Condition(s) Observed                                                                 | Measurements                                                                 | Response(s)                                                                 |
|-----------------------------------|--------------------------------------|---------------------------------------------------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Erber et al. 2013 [19]            | Movement & social contact            | Transfer from group housing to individual housing with initial riding                  | Stress: salivary cortisol<br>Stress: heart rate<br>Stress: heat rate variability<br>Activity: locomotion<br>Stress: salivary cortisol<br>Stress: heart rate<br>Stress: plasma cortisol | Increase after transfer<br>Increase during transfer<br>Decrease after transfer and after riding (= increase of sympathetic activity)<br>Decrease after transfer<br>No change between housing conditions<br>No change between housing conditions<br>Low after work—further decrease with increased withdrawn posture<br>Withdrawn posture 1–4 times every 30 min |
| Fureix et al. 2012 [22]           | Movement & social contact            | Horses showing normal and horses showing withdrawn posture under conditions of no free movement and no free social contact | Activity: body posture<br>Activity: head, ear, eye movement<br>Activity: response to tactile stimuli<br>Activity: response to sudden approaching person<br>Activity: response to novel objects<br>Behavioural scores<br>Stress: heart rate<br>Stress: salivary cortisol<br>Diurnal rhythm heart rate and salivary cortisol | Reduced in withdrawn posture<br>Reduced in withdrawn posture<br>Reduced in withdrawn posture<br>Reduced in withdrawn posture<br>Higher in individual than in group housing<br>No difference<br>No difference<br>No diurnal rhythm under either condition |
| Harewood and McGowan 2005 [16]    | Movement & social contact            | Group versus individual housing                                                       | Nearest neighbour<br>Activity: grazing<br>Behaviours<br>Abnormal behaviour<br>Stress: faecal glucocorticoid metabolites | Paddock weaned foals stayed near conspecifics for longer<br>Higher in paddock weaned foals<br>Greater variety in paddock weaned foals<br>Greater in stable weaned foals<br>No difference |
| Heleski et al. 2002 [12]          | Movement & social contact            | Paddock-kept weanlings versus stable housed weanlings                                  | Behaviour: positive cognitive bias<br>Stress: faecal glucocorticoid metabolites<br>Stress: heart rate variability<br>Abnormal behaviour | Enhanced in horses on pasture with social contact<br>Lower in group housing<br>Lower in group housing<br>Circling in horses in single boxes without paddock<br>Abnormal behaviour |
| Löckener et al. 2016 [10]         | Movement & social contact            | Living at pasture with social contact following single box housing                    | Abnormal behaviour                                                         | More frequent in stabled horses |
| Niederhöfer 2009 [17]             | Movement & social contact            | Comparison between group housing, single box without paddock, and single box with paddock | Abnormal behaviour                                                         | All horses moved from group housing to individual housing with paddock<br>Abnormal behaviour<br>Stress: faecal glucocorticoid metabolites<br>Stress: heart rate variability<br>Abnormal behaviour |
| Reference                  | Restriction                                      | Condition(s) Observed                                                                 | Measurements                                                                 | Response(s)                                                                 |
|----------------------------|--------------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Rivera et al. 2002 [15]    | Movement & social contact                        | Stable housing versus keeping at pasture                                                | Stress: heart rate                                                           | Lower in stabled horses                                                   |
|                            |                                                  |                                                                                       | Illness: gastric acidosis                                                      | More frequent in stabled horses                                           |
|                            |                                                  |                                                                                       | Trainability: duration training procedure                                     | Longer in stabled horses                                                  |
|                            |                                                  |                                                                                       | Trainingability: duration habitation groundwork                                | Longer in stabled horses                                                  |
|                            |                                                  |                                                                                       | Behaviour: bucking and jumping                                                | Greater in stabled horses                                                 |
|                            |                                                  |                                                                                       | Stress: plasma cortisol                                                       | More frequent in stabled horses                                           |
|                            |                                                  |                                                                                       | Trainability: between mount and dismount                                       | No difference                                                             |
|                            |                                                  |                                                                                       | Behaviour: aggression                                                         | No effect of housing conditions                                           |
|                            |                                                  |                                                                                       | Stereotypies: oral                                                            | Lower in housing with window and straw bedding                            |
|                            |                                                  |                                                                                       | Stereotypies: oral                                                            | Higher with grain feeding                                                  |
|                            |                                                  |                                                                                       | Trainability: equitation and training                                          | Number of meals per day had no effect                                      |
|                            |                                                  |                                                                                       | Activity: restlessness before training                                         | No difference                                                             |
|                            |                                                  |                                                                                       | Behaviour: aggression                                                         | Greater in single housed horses                                           |
|                            |                                                  |                                                                                       | Stereotypies: oral                                                            | More frequent in horses in single housing                                 |
|                            |                                                  |                                                                                       | behaviour: defecation during training                                         | More frequent in horses in single housing                                 |
| Ruet et al. 2019 [43]      | Movement & social contact                        | Housing with window opening towards the external environment and straw bedding compared with housing with no window and non-straw bedding, different forage: grain | Trainability: between mount and dismount                                       | More frequent in stabled horses                                           |
|                            |                                                  |                                                                                       | Behaviour: aggression                                                         | No difference                                                             |
|                            |                                                  |                                                                                       | Stereotypies: oral                                                            | Greater in single housed horses                                           |
|                            |                                                  |                                                                                       | Trainability: equitation and training                                          | No difference                                                             |
| Sondergaard and Ladewig    | Movement & social contact                        | Effect of single versus group housing on training                                     | Activity: restlessness before training                                         | No difference                                                             |
| 2004 [35]                  |                                                  |                                                                                       | Behaviour: biting, kicking during training                                     | Greater in single housed horses                                           |
|                            |                                                  |                                                                                       | Behaviour: defecation during training                                         | More frequent in horses in single housing                                 |
|                            |                                                  |                                                                                       | Trainability                                                                   | Horses in group housing passed more training stages                       |
| Vitale et al. 2013 [53]    | Movement & social contact                        | paddock turnout versus individual box housing versus fixed in a stock                 | Stress: heart rate variability                                                 | Decreased with reduced locomotion (= increased sympathetic activity)       |
|                            |                                                  |                                                                                       | Behaviours: standing alert, aggression, occupation with equipment, occupation with bedding, dozing, sternal recumbency and lateral recumbency | More frequent in the horses with no turnout                                |
|                            |                                                  |                                                                                       | Activity: walking, standing/watching                                           | More frequent in the horses with no turnout                                |
|                            |                                                  |                                                                                       | Trainability: willingness to perform                                           | Enhanced in horses with turnout                                           |
|                            |                                                  |                                                                                       | Trainability: duration of training                                             | Shorter in horses with turnout                                            |
|                            |                                                  |                                                                                       | Locomotion                                                                    | No difference                                                             |
|                            |                                                  |                                                                                       | Stress: heart rate variability measures SDNN, RMSSD and LF/HF                  | Higher sympathetic activity                                               |
|                            |                                                  |                                                                                       | Behaviour: lying down                                                         | when horses were stabled in single boxes                                  |
|                            |                                                  |                                                                                       | Trainability: willingness to perform                                           | Longer when horses had group turnout                                       |
|                            |                                                  |                                                                                       | Behaviour: standing alert, dozing, eating, occupation                         | Slightly better when the horses had turnout                                |
| Werhahn et al. 2011 [38]   | Movement & social contact                        | No turnout compared to turnout                                                       | Locomotion                                                                    | No change                                                                  |
|                            |                                                  |                                                                                       | Stress: heart rate variability measures SDNN, RMSSD and LF/HF                  | No change                                                                  |
|                            |                                                  |                                                                                       | Behaviour: lying down                                                         | No change                                                                  |
|                            |                                                  |                                                                                       | Trainability: willingness to perform                                           | No change                                                                  |
|                            |                                                  |                                                                                       | Behaviour: standing alert, dozing, eating, occupation                         | No change                                                                  |
| Werhahn et al. 2012 [21]   | Movement & social contact                        | Single box housing, individual turnout, group turnout                                | Locomotion                                                                    | No change                                                                  |
|                            |                                                  |                                                                                       | Stress: heart rate variability measures SDNN, RMSSD and LF/HF                  | No change                                                                  |
|                            |                                                  |                                                                                       | Behaviour: lying down                                                         | No change                                                                  |
|                            |                                                  |                                                                                       | Trainability: willingness to perform                                           | No change                                                                  |
|                            |                                                  |                                                                                       | Behaviour: standing alert, dozing, eating, occupation                         | No change                                                                  |

Table 1. Cont.
| Reference                  | Restriction                        | Condition(s) Observed                                                                 | Measurements                                                                                                                                  | Response(s)                                                                                   |
|----------------------------|------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Wille 2010 [24]            | Movement & social contact          | Open barn housing, individual box housing, tied up in stalls                         | Stress: faecal glucocorticoid metabolites  
Behaviour: standing  
Behaviour: lying on the chest  
Behaviour: lying on the side  
Locomotion  
Behaviour: food consumption          | Lower in open barn system  
Longer when tied in stalls  
Longer in open barn system or individual boxes  
Longer in open barn system  
More in open barn system  
No difference |
| Yarnell et al. 2015 [13]   | Movement & social contact          | Single housing with no contact (SHNC), group housing with full contact (GHFC), paired housing with full contact (PHFC) | Stress: faecal glucocorticoid metabolites  
Stress: eye temperature  
Behaviour: standing  
Behaviour: active and social negative behaviours  
Trainability: handling               | Higher in SHNC  
Lower in GHFC  
Lower in GHFC  
Higher in GHFC and PHFC  
More difficult with SHNC horses   |
| Lesimple et al. 2020 [54]  | Movement & feed                   | Change from single box with no paddock to housing with turnout and ad lib hay        | Behaviour: vigilance, excitement and locomotion  
Behaviour: feeding with ears laid back  
Stereotypies  
Blood: oxytocin  
Blood: cell counts, serotonin | Decreased with turnout and ad lib hay  
Decreased with turnout and ad lib hay  
Decreased with turnout and ad lib hay  
Increased with turnout and ad lib hay  
No difference   |
| Bachmann et al. 2003 [48]  | Movement, social contact & feed    | Restricting feed and daily pasture                                                  | Stereotypies: crib-biting, weaving and box-walking                                           | Increased                                                                                   |
| Mal et al. 1991 [14]       | Movement, social contact & feed    | Horses of different temperaments; housing in isolation (ISS), at pasture (P), in individual boxes with social contact (C) | Behaviour: time eating grain, grain-eating bouts  
 Behaviour: forage-eating bouts  
 Activity: distance travelled, time spent trotting, number of trotting bouts, number of standing bouts, number of total activity bouts  
 Activity: duration standing  
Triiodothyronine  
 Stress: faecal glucocorticoid metabolites | More in horses of medium and highly reactive temperaments in isolation (ISS)  
Longer in calm horses at pasture  
More in isolation horses       |
| Marr et al. 2020 [25]      | Movement, social contact & feed    | Change from group housing to individual housing, and initial training                | Behaviour: motor laterality  
Behaviour: sensory laterality  
Stress: Immunoglobulin A | Less in isolation horses  
Highest in isolation horses  
Increased after change from group to individual housing after 24 h, 48 h, and 1 week.  
Increased after 24 h, 48 h, and 2 months of initial training  
Left shift for 1 week after change from group to individual housing, and after 2 months of initial training  
Left shift 24 h after change from group to individual housing, and (not significantly) 24 h after initial training  
Decreased (not significantly) after change from group to individual housing, and 24 h after initial training |
2. Materials and Methods

From August 2020 to February 2021, we searched the research platforms Research Gate, PubMed, Web of Science, Science Direct and Google Scholar for studies on social contact, social companionship, free movement and unlimited access to roughage in horses. We identified 38 studies (Table 1 and Table S1) on behavioural and physiological responses to management conditions in which one or more of the four proposed basic needs were restricted, and this will be the basis of this literature review. Information on the horses observed in the studies and the management conditions they lived under are given in the Supplementary Materials (Table S1). Of the studies we identified, 17 evaluated horses’ responses to the given management situation, and 21 studied horses’ responses to changes in management conditions. One study is cited, but not included in the analysis, as it describes the horses’ responses to particular management conditions but does not analyse responses to management restrictions.

As horse housing is a complex setting, isolating only one of the aspects is very difficult. Therefore, only a few studies have analysed changes in only one of the proposed basic needs, and most consider two or more needs simultaneously (see Table 1). These generally compared two or more horse groups under housing conditions that differed in one or more needs (see Table 1), but a few examined changes in housing conditions of one group.
2.1. Data Processing

Four steps were applied in the evaluation of the literature (Table 1 and Figure 1). Firstly, the literature was assigned to the proposed basic needs that were restricted. Secondly, the studies were categorized according to the type of response shown by the horse, and thirdly, we assessed whether changes in the behavioural and physiological reactions indicated that the restrictions were compromising the horses’ welfare. Finally, the frequencies of studies reporting responses were compared with the frequency of those reporting no responses to the restrictions.

Figure 1. Number of reports of responses (dark colours, i.e., black and blue) versus number of reports of no response (light colours: skin and yellow) to restrictions in proposed “basic needs” described for response types across all studies. Abnormal Behaviour responses were significantly shown across all studies (Binomial Test: \( p = 0.02 \)). Responses were also shown when social contact, free movement and access to roughage were mutually restricted (Binomial Test: \( p < 0.001 \)). More detailed information on the responses, the test conditions and the horses included in the studies are given in Table 1 and in the Supplementary Materials (Table S1).
The studies were grouped according to the proposed basic needs that were restricted (Table 1):

1. No basic need restricted, \( n = 1 \)
2. Social Contact restricted, \( n = 4 \)
3. Social Companionship restricted, \( n = 1 \)
4. Free Movement restricted, \( n = 4 \)
5. Access to Roughage restricted, \( n = 3 \)
6. Social Contact and Access to Roughage restricted, \( n = 1 \)
7. Free Movement and Social Contact restricted, \( n = 16 \)
8. Free Movement and Access to Roughage restricted, \( n = 1 \)
9. Free Movement, Social Contact and Access to Roughage restricted, \( n = 7 \)

The studies were grouped according to evaluated behavioural and physiological measurements. The terms “shown” and “not shown” indicates whether the horses displayed any of the following types of responses to management conditions or not (Table 1, Figure 1):

a. Manuscripts evaluating ‘Stress Responses’, \( n = 16 \), methods of measuring ‘Stress Responses’, \( n = 21 \)
   i. shown, \( n = 14 \)
   ii. not shown, \( n = 7 \)

Stress responses include increased metabolic rates and reduced body condition score [11], reduced growth rate [12], reduced eye temperature [13] and triiodothyronine and thyroxine excretion [14]. Physiological responses include changes in cardiovascular functions (heart rate [15–19], heart rate variability [19–21]), excretion of catecholamines [14], changes in stress hormone levels (blood cortisol [14,15,22], salivary cortisol [16,19,23], faecal glucocorticoid metabolites [12,13,17,20,24,25]), faecal immunoglobulin A [25], increased gastric acidosis [27] and changes in EEG wave patterns [26]. Behavioural parameters comprise changes in horses’ motor and sensory laterality [25,28–32] and changes in their positive or negative expectations towards their environment, i.e., in their cognitive bias [10].

b. Manuscripts evaluating ‘Active Responses’, \( n = 24 \), methods of measuring ‘Active Responses’, \( n = 33 \)
   i. shown, \( n = 22 \)
   ii. not shown, \( n = 11 \)

Horses may show increased aggressive behaviour towards each other and/or towards people [11,18,22,26,33–38]. They may show more interest in novel objects [38–40] and increased cooperativeness during training (i.e., trainability) [13,21]. They may seek close proximity to their conspecifics more frequently, as observed by applying nearest neighbour analysis [36]. Furthermore, horses may become more active [14,15,19,21,24,38–40] and may also show more hurried eating behaviour [14].

c. Manuscripts evaluating ‘Passive Responses’, \( n = 17 \), methods of measuring ‘Passive Responses’, \( n = 23 \)
   i. shown, \( n = 15 \)
   ii. not shown, \( n = 8 \)

Passive responses include reduced reactivity towards stimuli and human presence [15, 22,26,40,41], reduced close contact with conspecifics [35] and reduced trainability [15,35,43]. Reduced activity [42] was evaluated by measuring the time spent lying down [11,21,39], moving [11,19], and the distance moved [20]. Some horses may show depressive-like behaviours [22].

d. Manuscripts evaluating ‘Abnormal Behaviour’, \( n = 14 \), methods of measuring ‘Abnormal Behaviour’, \( n = 17 \)
   i. shown, \( n = 14 \)
   ii. not shown, \( n = 3 \)
Abnormal Behaviours include self-harming (i.e., redirected behaviour such as self-biting [8]), stereotypies such as crib-biting, wind-sucking, weaving and box-walking [14,41,48], as well as other behaviours such as, wood-chewing, bed-eating, manure-eating, rug-chewing or tearing, stable kicking, aggression towards humans and masturbation [8,44,55].

2.2. Data Analysis

The R-Project statistical software (R Development Core Team 2021, https://www.r-project.org/) was used for the statistical analysis and Excel for creating the figures when analysing the frequencies of studies on basic need restrictions. Some of the data were not normally distributed (Shapiro–Wilk Test). Therefore, Generalized Linear Models (GLMs) for multivariate testing with fixed factors were applied. For a general approach, we analysed the frequency of studies reporting reactions or no reaction under the particular restrictions of basic needs and the different responses shown. The GLM (formula = number of manuscripts evaluating response~response versus no response + response type, family = poisson (identity), data = Dataset) was used. We continued by applying a nested Generalized Linear Model (GLM) to analyse whether manuscripts reported differences for showing or not showing responses nested within the different types of response. Therefore, the GLM (formula = number of manuscripts. evaluating response~response versus no response % in % response type, family = poisson (identity), data = Dataset) was applied. The full statistical data are given in the Supplementary Materials (File S1). Binomial Tests were applied to compare the frequencies of showing or not showing certain types of responses under certain management restrictions. All tests were two-tailed, and the significance level was set at 0.05.

3. Results

Overall, a significant number of studies reported that horses did show responses to restrictions in the proposed basic needs (responses shown: n = 90, not shown: n = 29; GLM: n = 37, z = 4.08, p < 0.001; Table 1, Figure 1, File S1). However, reports on whether horses showed responses differed between the particular response types (GLM: n = 37, z = −2.57, p = 0.01; Figure 1, Table 1, File S1).

Of the studies on changes in behavioural and physiological measurements of ‘Stress Responses’, n = 13 studies reported that horses showed responses and n = 7 did not (Table 1, Figure 1). The studies did not clearly indicate stress responses for single restrictions, as when studies found several stress measurements changed, i.e., indicating stress, the same study or other studies also found other stress measurements remained unchanged, i.e., indicating no stress. When the reactions to all the different restrictions were compared, the number of reports showing stress responses correlated with the number of reports showing no response (GLM: n = 37, z = 2.49, p = 0.01; Figure 1, Table 1, File S1).

The same was true for the ‘Active Responses’, with n = 14 studies reporting that active responses were shown and n = 8 reporting they were not (Figure 1, Table 1). Again, while many parameters changed almost as many did not change when analysing a particular restriction and there was a general correlation between active responses and no active response over all the basic need restrictions (GLM: n = 37, z = 2.63; p = 0.008, Figure 1, Table 1, File S1).

‘Passive Responses’ were reported in n = 14 studies and no ‘Passive Responses’ for n = 8 studies (Figure 1, Table 1). ‘Passive Responses’ to particular restrictions indicated more clearly than ‘Stress Responses’ and ‘Active Responses’ that horses responded with changes in behaviour to certain restrictions. The literature revealed only a trend in correlation between the horses showing passive responses to those showing no passive response when comparing all the different restrictions in the basic needs (GLM: n = 37, z = 1.85, p = 0.06; Figure 1, Table 1, File S1).

Finally, a significant number of horses demonstrated the response ‘Abnormal Behaviour’ in response to any restriction in basic needs (‘Abnormal Behaviour’: n = 12, no ‘Abnormal Behaviour’: n = 3, Binomial test: p = 0.02, Figure 1). Horses reacted more clearly
by either showing abnormal behaviour or not showing abnormal behaviour to particular restrictions, as there was again only a trend for a correlation between reports of abnormal behaviour and reports of no abnormal behaviour across the studies on all the different restrictions examined (GLM: \( n = 37, z = 1.74, p = 0.08 \); Figure 1, Table 1, File S1).

The literature provides no clear conclusion as to whether horses generally show responses to restrictions in just one of the parameters of social contact, social companionship, free movement and access to roughage in isolation (Figure 1). For most of the comparisons the sample sizes were too small for applying statistical tests, the few that allowed statistical testing revealed no difference between measurements that show and those that do not show a response to the restrictions (Binomial tests: all \( p > 0.05 \); Figure 1). When social contact, free movement and access to roughage were mutually restricted, horses showed behavioural and/or physiological responses (Binomial test: \( p < 0.001 \); Figure 1).

4. Discussion

The aim of this study was to evaluate whether certain measurements can be considered reliable indicators for the analysis of animal welfare under basic need restrictions by analysing the results published in the literature. The interpretation of the studies calls for caution as positive reporting biases may result in more studies that prove a certain measurement to be effective than those reporting no effect [56]. However, the literature also contains several studies that actually report missing responses of horses to the measurements under observation. We therefore found the results of the meta analysis of these studies worth discussing.

Especially the development of abnormal behaviour and stress responses under the long-term stress of compromised environmental conditions has been considered a maladaptive strategy which does not provide the animals with options to deal with such conditions [8,57,58]. When animals develop these responses, they are said to be clearly suffering [58,59]. The present literature review provides evidence that this claim is justified in horses, especially in relation to abnormal behaviour. Horses develop significant levels of abnormal behaviour when social contact, social companionship, free movement and access to roughage are compromised. Therefore, it appears to be justified to use the display of abnormal behaviour as a behavioural animal welfare indicator when analysing the quality of horse housing and training, as has been established for animal welfare protocols [60]. However, it remains debatable whether a long-term display of abnormal behaviour provides strong evidence of a horse suffering under its present management conditions. Stereotypic behaviour may have developed under previous conditions and persist, even when management and training return to favourable conditions [45,46,57]. A recent development in EEG wave pattern analysis [26] offers promising new insights into this debate. Horses that had consistently displayed stereotypic behaviour for at least one year and lived under restricted management conditions showed EEG wave patterns comparable to those indicating negative emotional states in humans. However, caution should be exercised when evaluating welfare in horses displaying stereotypic behaviour as horses secrete dopamine when engaging in such behaviour and this elicits a positive emotional state in the animal (see for review: [61]).

Similarly, the measurement of behavioural and physiological stress parameters did not necessarily indicate that all horses experienced stress in compromised management conditions (Figure 1). Some studies found that horses did respond with behavioural or physiological stress parameters, and others did not (Table 1). This discrepancy may be due to difficulties in assessing long-term stress. When animals suffer stress for longer periods, such as when their environmental requirements are restricted for a long time, several physiological parameters, such as stress hormones and cardiovascular functions may return to base levels or below [13,25,62,63].

There are promising stress parameters that may allow long-term stress to be evaluated, such as immune cell suppression, changes in motor laterality [25,64], increased hemispheric laterality and EEG wave patterns analogous to those measured in humans with negative
emotional arousal [26]. However, there is not yet sufficient evidence for these to be included in the present literature survey because they have only been studied in a few pioneering papers [25,26,64,65].

There may also be individual differences between horses in their stress resistance and the importance an individual attaches to any particular stressor [63]. In addition, previous experience with the restrictions in basic needs may be a factor. For example, horses that were born and raised in a stabled environment may be less stressed by restricted movement than horses raised at grass and then moved to a stabled environment [25]. Moreover, horses that had previously experienced individual housing did not display any significant differences in physiological stress responses between individual housing with semi-contact to conspecifics and group housing [13,24], whereas horses that were naïve to individual housing showed significant physiological stress responses when moved from group to individual housing [17,19,25]. A combination of several physiological and behavioural stress parameters may provide the strongest evidence for stress in horses as some studies found conflicting results when comparing a limited spectrum of physiological and behavioural data [63].

However, the proportion of horses showing passive responses supports the claim that many horses suffer long term stress under the investigated management restrictions [22,52,66]. Passive responses, such as reductions in activity, feeding, behaviour displays, contact to persons or other conspecifics and reactions to the environment indicate that horses withdraw from external stimuli and may show a depressive-like state [22,66]. These responses are maladaptive for animals such as horses, which are both flight animals that rely on fast responses to acute challenges and social animals that rely on fast responses to social challenges [9].

Interestingly, the analysis of ‘Active Responses’ did not provide a clear conclusion. Some studies reported that horses showed active responses when the animals were faced with restricted basic needs and others did not (Table 1 and Table S1). It may be difficult to clearly distinguish the level of activity that constitutes a stress response, as elevated aggression and movement may counteract mild stress [34,37].

As only very few studies succeeded in isolating the effects of restrictions in just one of the four proposed basic needs of social contact, social companionship, free movement and access to roughage, a clear statement on whether animals can generally cope with the particular restrictions remains elusive. However, there were sufficient studies on combined restrictions in social contact, free movement and access to roughage, and when the horses’ environments were restricted in these three conditions, they appeared to suffer, as ‘Abnormal Behaviour’ and ‘Passive Response’ had clearly developed. This is consistent with the finding that abnormal behaviour display may be caused by a variety factors (e.g., genetics, rearing conditions, housing and feeding [48]).

5. Conclusions

We conclude that under combined restrictions of social contact, social companionship, free movement and access to roughage horses display signs of suffering. The literature available on individual so called “basic needs”, does not allow us to isolate the effect of each of them, especially in the case of social companionship. However, the development of abnormal behaviour and passive coping strategies, can be considered signs of suffering, and these were displayed under separate restrictions in social contact, free movement and free access to roughage, as well as under combined restrictions of two or more of the proposed basic needs.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ani11061798/s1, File S1: Statistical Data. Complete Generalized Linear Models (GLMs), Table S1: Summary table of literature content. More detailed information on the restrictions, the horses, their management and their responses.
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