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How outing conditions relate to the motivation of movement-restricted cattle to access an outdoor exercise yard

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ABSTRACT

Assessing animal motivation to access a given resource is one method available to evaluate what to provide in the living environments of captive animals. Providing increased opportunities for movement can be seen as an important source of enrichment, but we need to know the point of view of the animal. The objective of our study was to test a novel combination of behaviours in order to assess the motivation of cows to access an outdoor exercise paddock. Three trials were conducted, each enrolling 15–16 tie-stall-housed cows as a model for movement-restricted animals. Cows were provided with access to an outdoor exercise yard 5 days/week for the duration of the trial, each trial presenting different conditions such as paddock size, duration of access and animal handling. We recorded the trips' durations and cows' behaviours during the trips going to (go-out) and coming back (go-in) from the paddock. LMr comparisons on PCA were used to assess cow motivation profiles. The same two dimensions of speed and stop quality emerged from the PCA in all three trials, showing the method's robustness. Additionally, three motivation profiles were established, representing how the cows' motivation was affected by the conditions prevailing in each trial.

1. Introduction

Considering the welfare of animals, the satisfaction of the needs is a central issue. Listing out what are the needs of an animal in an accurate and thorough manner represents a more complex task than could appear at first. Even among the scientific community, the concept of need itself remains controversial (Hughes and Duncan, 1988; Jensen and Toates, 1993): this is linked not only to the basic definition of a need, but also to how we should – and if we should – differentiate between basic and opportunistic needs. Thus, a less controversial manner to address questions of what should be provided to animals is to work on the basis of their motivation to perform certain activities or to access certain resources. Motivation can be defined as the tendency of an animal to perform a behaviour, and is therefore thought to reflect an animal's desire to perform said activity or behaviour (Kirkden and Pajor, 2006). Motivation can stem from internal factors (e.g., hunger) or from a subjective experience (e.g., the pleasure to eat a certain type of feed), and while it is often thought of as positive, it can also be negative, i.e., if it aims to avoid a status or an event perceived by the animal as negative. Following this idea of motivation relating to a context, most studies examining the motivation of animals rely on choice-based tests, where the animal must choose between two (or more) options, or on tests based on principles of operant conditioning to assess motivation (Fraser and Matthews, 1997; Kirkden and Pajor, 2006). However, one can question the extent to which these tests measure the intrinsic level of motivation of an animal for one specific activity or behaviour. Indeed, an animal's response to those tests is context-dependent, and one could argue that these measure preference for one activity over another, rather than the intrinsic motivation for that specific activity. Moreover, while such tests may allow us to rank the motivation of an animal for different stimuli, it does not allow us to measure the degree of motivation for any one stimulus. Motivation may also vary in intensity, as animals may be motivated to perform an action to different degrees, this variation in intensity may be shown through behaviours relating to the stimuli or situation of interest. Studies that aim to evaluate this variation use different measures, such as the amount of work an animal may be willing to put in (Sørensen et al., 2004; Wenker et al., 2020), or the time an animal takes to access a given resource or stimuli (Formanek et al., 2008; Gibbons et al., 2010), and represents another method to assess the motivation of animals in studies. Finally, motivation can also be assessed by placing an animal in an environment which contains or is deprived of a given resource and observe its subsequent responses, such as increases

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in the expression of certain types of behaviours indicative of frustration (e.g., aggression or perseverance behaviours; Bokkers et al., 2004; Burokas et al., 2012; Haskell et al., 2004).

The provision of living environments granting captive and/or domesticated animals with opportunities to engage in various behaviours they are motivated to perform is the object of efforts from multiple stakeholders including citizen organizations, the scientific community, and animal caretakers. One topic of interest, specifically for the public, is the question of the ability of captive animals to move, or the freedom of movement. Most captive species experience restrictions in their freedom of movement – albeit to different degrees –, which contrasts with public expectations; in the case of farm animals, freedom of movement is considered as one, if not the most important living condition to be provided (Schuppli et al., 2014).

While the literature pertaining to motivation is populated with for example articles relating to the question of food choice or social preference (Kirkden and Pajor, 2006), the animals' motivation for movement has been the object of fewer elements of scientific literature. Locomotion has often been used as a measure reflecting the motivation of animals for movement; most studies published on the matter assessed the rebound in locomotor activity of individuals once moved out of a restrictive environment to an environment permitting more freedom of movement (Jensen, 1999; Loberg et al., 2004; Veissier et al., 2008). Veissier et al. (2008) also evaluated the time animals took to travel towards a designated exercise area, hinting at a greater motivation exhibited in the form of shorter travel times. However, this measure could also reflect a difference in the locomotor ability of different animals. Compounding with other measures such as the amount of encouragement needed to get the animal to travel to the designated area could help address these issues and yield a more precise portrait of the motivation of animals, but no studies to date have reported on such variables and we propose here to use this new method.

Studying animals with reduced freedom of movement in their housing environment represents an opportunity to better understand the impact of the provision of greater opportunities for movement on their motivation for such potential sources of enrichment. As such, dairy cattle provide a convenient model to improve our knowledge of animal motivation for movement. Some housing systems for dairy cattle restrict their freedom of movement, especially tie-stall (adult cattle) and individual crate (calves) systems. The indoor housing systems they are raised and kept in can be considered under-stimulating, highly predictable environments, particularly when compared to the outdoors (Morgan and Tromborg, 2007). Moreover, dairy cattle of all ages are motivated for locomotion. Periods of restriction to their movement were found to lead to a rebound in locomotor activity/behaviours, both in calves (Jensen et al., 1999, 2004; Sisto and Friend, 2001) and in adult cows (Veissier et al., 2008). The provision of exercise areas is thus a potential solution to enrich these animals. This is particularly the case for outdoor areas which are, by nature, more stimulating for animals, containing more diversity and sources of stimulation, which can serve to improve cow motivation to access them. Indeed, Studies show that cows prefer pasture to other types of exercise areas (Smid et al., 2020) and even in winter conditions (Shepley et al., 2016). These studies were often conducted in free-stall-housed cows, and not with more severely restricted animals such as cows tied all year long.

Multiple factors external to the cow can impact not only her motivation to access the outdoors, but also her ability to express said motivation. These factors can include the time of day (e.g., Legrand et al., 2009), the meteorological conditions, or the provision of additional resources such as feed and water (e.g., Shepley et al., 2017), which are known to have an effect on the cows' motivation and preferences for outdoor access. Other conditions which can be managed more directly such as the duration of outdoor access or the amount of space provided may also affect the cows' motivation due to their impact on the opportunities (e.g., expression of social or exploratory behaviours) the outdoor area provides them. Interactions with handlers can equally influence a cow's motivation, but are required for the safe and effective implementation of outdoor access. Cows with no outdoor experience are at risk of slips and falls, and risky behaviours such as running must be limited until the cows become familiar with the process and environment. Indeed, while willit undoubtedly influence animal response, human intervention is intrinsic to the application of treatment in this study. Moreover, human behaviour was standardized across trials and was determined by the behaviour of the animal. As a result, they were included as indicators of motivation. Our study thus aimed to evaluate with a new analysis method, how dairy cows housed in a tiestall system all year round - as a model representative of animals with greatly reduced opportunities for movement on a daily basis – are motivated to access an outdoor exercise yard. Our new method focussed on compounding behavioural measures observed during trips with measures of trip speed or duration in order to evaluate motivation. We collected data in three trials held during a different season each, and with each trial presenting different constraints during outing (i.e., the process of letting the cows out to and from the exercise yard). We hypothesized that cows which are more motivated to access the exercise yard would complete the go-out trip in shorter times than less motivated individuals and would require fewer interventions from handlers, and would exhibit slower speed upon the go-in (or return) trips. Through our assessment of go-out and go-in (return) trips, we also assessed whether the amount of space provided in the paddock and the duration of the outing affected the motivation of cows. Moreover, we hypothesize that cows will be more motivated to access a larger exercise area compared to a smaller space.

2. Materials and methods

2.1. Ethical notes

A series of three independent trials (Winter, Summer and Fall 2019) was conducted at the McGill University Macdonald Campus Dairy Complex (Ste-Anne-de-Bellevue, QC, Canada) and the use of animals in these projects and all procedures were approved by the Animal Care Committee of McGill University and affiliated hospitals and research institutes (protocol #2016–7794).

2.2. Animals and housing

This study spanned across three independent trials with markedly different contexts (outdoor space allotted, duration outside, handler interventions, outdoor conditions, etc…). While this meant all three trials had to be analysed separately, it allowed us to test the robustness of our method across three vastly different contexts. In the Winter and Summer trials, 16 naïve tie-stall-housed Holstein dairy cows were selected and grouped in pairs balanced in parity and days in milk. Cows from each pair were then randomly assigned to one of two groups of eight cows each, either the group of treatment cows (T), on which we collected our data, or the group of companion cows (C), which accompanied T cows on their way out to avoid isolation reactivity on the motivation. In the Fall trial, 15 cows were assigned to the outdoor access treatment and grouped into five groups of three T cows each (no companion cows, one cow per group having previous experienced outdoor access in an earlier trial). In order to ensure only sound cows were enrolled in the study, all cows were evaluated for locomotion (we had them walk in a corridor and gave them a locomotion score (adapted from Flower and Weary, 2009). Only sound cows were then enrolled in the study (score below 3.5) according the ethics statement and the validity of our study. During the study, they were housed in a mechanically ventilated barn consisting of cubicle tie stalls (stall width of 1.3 m, bed length of 1.9 m, stall length of 2.1 m) fitted with rubber mats on which a 2 cm depth of wood shavings bedding was maintained. Alleyways inside the barn were made of grooved concrete. All cows had ad libitum access to water and were fed a total mixed ration four times per day, such that each cow always had feed in front of her. Cleaning of the alleyways and stalls occurred four times per day, equally distributed before and after the exit. Fresh wood shavings were provided as needed to maintain 2 cm of bedding per stall. Milking was conducted in-stall twice daily at 12-h intervals.

2.3. Procedures

2.3.1. General process

Cows went out, every morning for 1–2 h (treatment dependent) between 9 and 11 am, to an outside grassland exercise yard (1344 m^2) adjacent to the barn, in pairs (one T cow and one C cow) in the Winter and Summer, and in triads (three T cows) in the Fall (see Fig. 1). In the Winter and Summer, cows were trained during a nine-day period of habituation during which the conditions (time, space and number of pairs out) were changed in order to gradually acclimate individuals to external conditions and manipulations. After that, we applied outdoor access treatment to the cows five days a week for eight weeks (Winter and Summer) or five weeks (Fall). Based on an analysis of habituation time in the winter and summer trials, cows in the fall trial were habituated to experiment procedures over three days. Rather than gradually introducing the cows to the area, they were instead immediately placed in the experimental paddocks with one experienced cow who was already familiar with the process. In addition, in the fall trial no additional treatment was applied during outings: all animals exited in the same conditions for 5 weeks, allowing us to further test the robustness of our method (vs. treatment differences seen in the other two trials). The outdoor exercise area consisted of paddocks delimited by electric fencing. Neither feed, water nor shelter were provided during outdoor access. In the Winter and Summer, the size and the time spent in the paddock changed each week following a Latin square design, each pair assigned to one of the eight treatments: 1 h-20 m^2, 1 h-40 m^2, 1 h-60 m^2, 1 h-80 m^2, 2 h-20 m^2, 2 h-40 m^2, 2 h-60 m^2, 2 h-80 m^2. Two conditions had to be respected for the Latin square sequence: 1) No more than one pair per treatment on any given week; 2) No more than 40 m^2 difference in paddock surface for any given group between two consecutive weeks.

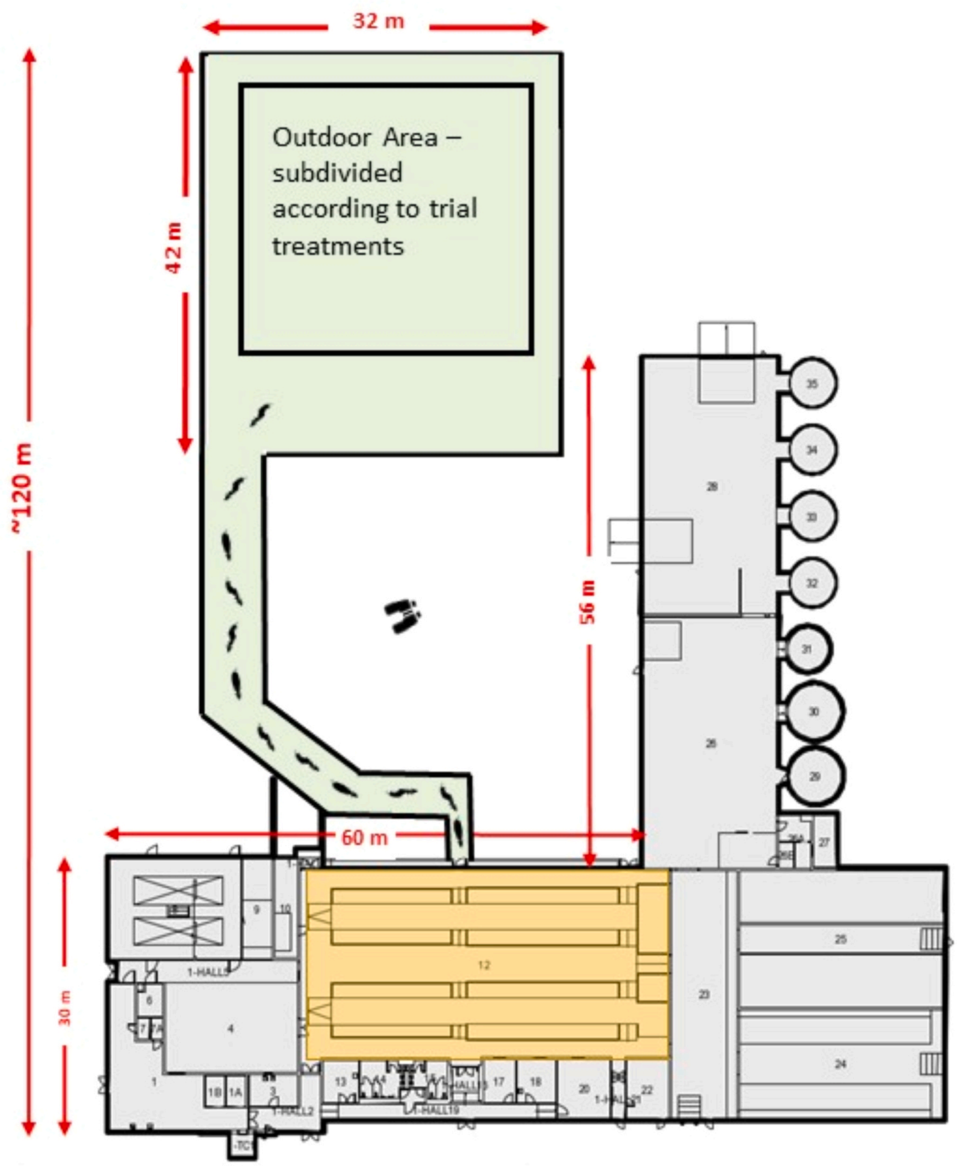

Fig. 1. Visual representation of the barn ( ) as well as the alley-way to the exercise area and exercise yard ( )used for all three trials. Image also shows placement of observer during outings ( ). Division of the yard depended on trial (winter and summer trial paddocks split into 20 m^2, 40 m^2, 60 m^2, or 80 m^2 and fall trial paddocks divided into 5 equal paddocks of 117 m^2).

The purpose of these conditions was to 1) ensure that no more than one pair would be assigned to any given treatment in a given week, such that every treatment would be represented on every one of the weeks, since the prevailing conditions may have differed from one week to the next; 2) avoid having drastic changes in the size of the paddocks experienced by the cows over the course of one week, as these could have caused a "shock" to the cows' motivation. It had been hypothesized that if such conditions were allowed to occur, it could generate a confounding factor in that some changes in the motivation of cows could be attributed to the large contrasts in size rather than to the new paddock size per se, with the difference between those difficult to ascertain. In the Fall, groups of cows were assigned for 1 h to a different paddock each week, all paddocks measuring 117 m^2 (9 m x 13 m; 39 m^2 per cow).

To access the outside exercise yard, cows had to walk in a 52.2 m long and 3.05 m wide outdoor corridor made of cattle fence and concrete floor covered with a thick layer ($\geq$ 2.5 cm) of sand in the first half, and a dirt surface in the second half. We observed the trip in the corridor for all days during the habituation period (winter and summer), and on the fourth or fifth days of each week during the treatment application period, maximizing the treatment experience of the cows for the study. Trips were standardized, albeit a bit differently in each of the trials (see below). During the trips, familiar handlers had to follow specific instructions to move the cows forward (Table 1), such that a behavioural observation could be established by an observer for each treatment cow during each trip.

2.3.2. *Winter trial*

The paddocks were covered in snow and/or ice. When the surface was deemed too dangerous (e.g., too icy), wood chips were added equally to each paddock, and sand was added in the corridor. The standardized procedure to lead the cows was the following: Two trained handlers led each pair, following the standardized handling instructions. They untied the cows and then led them by the halter to the door leading to the outside. Once out, the handlers remained beside the cows, and cows were then allowed to freely move forward in the corridor. Once in the yard, the pairs of cows were distributed, thanks to electric fences, between eight different paddocks, according to the plan of randomization. The week 3 and 6 were finally absent due to non-exit of the animals for very bad and cold weather.

2.3.3. *Summer trial*

The paddocks were covered with grass, which was grazed on by the cows during the first two days of outdoor access (during habituation). Trampling by the animals prevented the grass from growing back. The standardized procedure to lead the cows was the following: two or three trained handlers led each pair or individual cow, according to their behaviour. One of the three handlers untied the cows and then led them by the halter to the door leading to the outside, one at a time. Once all cows were out, handlers stayed beside the cows, with one handler positioned either at a 0 m (contact distance), a 2 m or a 7 m distance in front of the cows to prevent the cows to prevent fast running. The decision to lead individuals or pairs and the distance of the person in front was determined according to the previous behaviour of the cows. The more excited they had been, the more important the restrictions were. Once in the yard, the pairs of cows were distributed, thanks to electric fences, between eight different paddocks, according to the plan of randomization.

2.3.4. *Fall trial*

The paddock base was a short grass and bare ground surface, with a snow cover of variable depth depending on the weeks. Standardized procedure to lead the cows in fall is: three trained handlers led each triad. One of the three handlers untied the cows and then led them by the halter to the door leading to the outside, with a second handler going along to assist in the procedure. Once the entire group was out, one handler stayed beside the cows, and two handlers were positioned at the front 7 m and 14 m ahead of the cows to prevent fast running. Past this corridor, the pairs of cows were distributed, thanks to electric fences, between the five different paddocks according to the plan of randomization.

2.3.5. *Measures*

Trip observations began when the handlers allowed the two or three cows to move forward freely after they passed the barn's door. The treatment cow was always the first one to pass the door (winter and summer), whereas in the Fall, the cows in each triad were always brought outside following the same order. During the trip, an observer strove for minimum disturbance by strategic stationing and remaining unobtrusive. He took note of all occurrences of cows' behaviour related to the trip or their interactions with the handlers (Table 2). The observations ended when the treatment cows passed the gate at the end of corridor and entered in the exercise yard. The duration of the trips was also noted down.

2.4. *Statistical Analysis*

Before statistical analysis, we calculated the frequency by second for each behaviour, by dividing the number of occurrences by the duration of the trip.

Normality of the data or residuals was assessed graphically using Q-Q Plot. For each trial, we first calculated the difference between the duration of go-in and go-out trips for each day. We compared this difference to 0 by means of a t-test with a Bonferroni adjustment to account for the multiple comparisons. This adjustment yielded the following *P*-value thresholds for the three trials: 0.0033 for Winter, 0.005 for Summer, and 0.0021 for Fall.

We computed a principal component analysis (PCA) for each trial with the frequencies of behaviours, duration, and speed of cows for each trip, excluding data from the habituation phases. Some behaviours' frequencies are finally grouped during the process: Resist= Resisting a +b+ kicking+ head butting + forcing; FreeStop=Stop a + Freezing a; StopRBalk=Stop b+c+Freezing b+c. Others behaviours were removed because they had no good representability on the dimensions.

We opted for a PC loading criterion of $|0.5|$ or higher to consider that a variable was relevant to a specific component. We implemented a linear mixed-effects model for all factorial scores obtained (LMr) for each trial.

We first tested models to assess the trip effect. We have considered

Table 1
Steps followed by the handlers to have the cows move forward.

Instance	Step followed[1]		Description of action
The cow stops	Step 1	Talking, gentle OR	The handler talks to the cow using a calm and soft voice, or in a conversational tone. May also use quiet whistling.
		Clapping OR	The handler claps hands together or knocks on elements of the environment with hands or with an object (e.g., a stick).
		Waving	The handler waves the arms or an object up in the air (<45° from the body).
	Step 2	Contact, moderate	The handler pushes the cow forward, or gently taps its body with a hand or dewclaws with the foot.
	Step 3	Catching the halter	The handler catches hold of the cow's halter and induces a step forward, then releases the halter.
The cow balks	Step 1	Waving and talking	The handler talks, claps hands or waves the arms or an object in front of the cow to induce a half-turn.
	Step 2	Catching the halter	The handler catches hold of the cow's halter and makes the cow perform a half-turn, then releases the halter.

[1]Handlers were instructed to wait 10 s after one step before proceeding to the next step.

Table 2
Ethogram used to score the behaviour of the cows during the trips.

Behaviour	Description
Stopping	The cow stops while in a forward movement. The cow appears calm and relaxed: no tense in the body and no focus on a fixed point/item, ears move or stay in axial (relax) position. a) The cow resumes walking without any contact or action by the handler. b) The cow resumes walking directly following contact or action by the handler. c) The cow does not resume walking despite handler's action; halter is needed to have the cow resume moving forward.
Freezing	The cow stops while in a forward movement. The cow appears tense or fearful, with ears forward and full attention towards the item of focus. a) The cow resumes walking without any contact or action by the handler. b) The cow resumes walking directly following contact or action by the handler. c) The cow does not resume walking despite handler's action; halter is needed to have the cow resume moving forward.
Balking	The cow proceeds to move back, to head in the opposite direction to where she is led to go. a) The cow balks voluntarily or due to the presence or interaction of another cow. b) The cow balks due to contact with handler.
Resisting	When the cow I stopping, it resists moving (does not move and can pull back its head) in the direction the handler tries to get her moving into, and when it moves, it tries to pass the handler by force.
Running	The cow trots or runs. a) The cow runs forward: ears are forward b) The cow takes flight, running away from a handler or a frightening situation: ears are backward.
Caracoling	The cow caracoles (alternates between run/trot and buck).
Kicking	The cow kicks towards the handler with one or more legs.
Head butting	The cow butts with her head towards the handler.
Forcing	The cow tries to force her way through or run/climb over a structure.
Vocalizing	The cow emits a vocalization.
Falling	The cow falls.

the following factors: (1) Trip as a fixed effect: go-in or go-out; (2) Days as a fixed effect: each observation day according the trial; (3) Trip x Days interactions as a fixed effect; (4) Animal nested within groups (pairs or triads formed according to parity and stage of lactation) as a random effect.

We also tested models to assess the effect of the size and the time spend in outdoor exercise yard. For these, we have considered the following factors: (1) Size as a fixed effect: there were 4 modalities 20 m^2, 40 m^2, 60 m^2 and 80 m^2; (2) Time as a fixed effect: 1 h or 2 h; (3) Size x Time interactions as a fixed effect; (4) Animal nested in groups (pairs or triads formed according to parity and stage of lactation) as a random effect.

When necessary, post- hoc comparisons were performed by the means of Tukey tests. The threshold of significance was $P \geq 0.05$, and tendencies between 0.1 and 0.05 are mentioned. Statistical analyses were performed in R (V 3.6.3) with the Factoshiny package for PCA; nlme, car and emmeans were employed for model analysis.

3. Results

3.1. Differences between go-out and go-in trip duration for each trial

In the Winter trial, the difference between go-out and go-in was significantly larger than 0 (t-test; t = 5.686; $P < 0.0033$; Fig. 1A) on the first habituation day: cows went faster heading back to the barn than on the way out. After the first day, this difference no longer differed from 0 (t-tests, $P > 0.0033$). This meant that cows did not go any faster on either one of the go-out or the go-in trips during all the habituation or treatment periods.

In the Summer trial, difference between go-out and go-in was significantly larger than 0 (t-test, t = 3.42, $P < 0.0021$; Fig. 1B) on the first two days of habituation: cows went faster heading back to the barn than on the way to the exercise yard. This difference is also present on habituation days 13, 14, 15, and 16, as well as on treatment weeks 1 and 4 (t-test; $P < 0.0021$). On the remaining habituation days and treatment weeks, cows did not go faster on either one of the trips (t-tests; $P > 0.0021$).

In the Fall trial, the difference between go-out and go-in trips was significantly greater than 0 (t-rest; t = 4.99; $P < 0.005$; Fig. 1C) on day 1: this meant that cows went faster when returning to the barn than on the way to the exercise yard. Between the 1st and the 9th day, this difference was not different from zero (t tests, $P > 0.005$): cows did not go faster on any one of either trips. From the 9th day onwards (with the exception of day 17), the difference between two trips was smaller than 0 (t-tests, $P < 0.005$) cows went faster on the way out compared to the way back to the barn.

3.2. Differences in Cows' behaviour during trips for each trial

For each trial, the PCAs of cows' behaviour during the trips revealed two dimensions with eigenvalues greater than 1 that, together, explained 59.93% (Winter trial), 59.71% (Summer trial), and 56.04% (Fall trial) of the variance. The first dimension was named "Trip Speed", opposing trip duration and speed with caracoling and running behaviours. The second dimension was represented by behaviours of resistance and balking behaviours (negative interactions) in opposition with free stopping behaviours. It was labelled "Stop Quality". The running behaviour is the only one which is correlated with the Stop Quality instead of Trip Speed component in the Summer trial.

In the Fall trial, LMr comparisons of cows' scores on the Trip Speed dimension revealed a significant day x trip interaction ($F_{17,272} = 5.05$, $P < 0.001$; Fig. 2): on the first two days, cows travel faster and engage in more running and/or caracoling behaviours on the go-in than on the go-out trip. After those days, the effect is seen to reverse, with cows traveling faster and running/caracoling more during the go-out than during the go-in trips (see Fig. 2). LMr comparisons of cows' scores on the Stop Quality dimension yielded no significant effect for day ($F_{8,281} = 0.75$, $P = 0.65$), trip ($F_{1,289} = 2.50$, $P = 0.12$) or for their interaction ($F_{17,272} = 0.16$, $P = 0.99$).

In the Winter trial, LMr comparisons of cows' scores on the Trip Speed dimension revealed no significant effect of day ($F_{5,78} = 0.76$, $P = 0.58$), trip ($F_{1,83} = 1.29$, $P = 0.26$) or their interaction ($F_{11,72} = 0.25$, $P = 0.93$). There was no significant effect for day ($F_{5,78} = 0.009$, $P = 0.58$), trip ($F_{1,83} = 1.29$, $P = 0.26$) or for their interaction ($F_{11,72} = 0.25$, $P = 0.93$) on the Stop Quality dimension either (Fig. 3).

In the Summer trial, LMr comparisons of cows' scores on the Trip Speed dimension revealed no significant effect for the interaction of day x trip ($F_{13,183} = 1.29$, $P = 0.26$). There was a significant effect of day ($F_{7,191} = 1.29$, $P < 0.001$): cows moved faster and engaged in more running/caracoling as time progressed. There was also a significant effect for trip ($F_{1,198} = 45.42$, $P < 0.001$), with cows traveling faster on the go-in trip than on the go-out (Fig. 4). The Stop Quality dimension had a significant effect for the day x trip interaction ($F_{13,183} = 3.15$, $P = 0.004$), but following adjustment for the multiple comparisons, only a spare few of the pair-wise comparisons turned out to be significant (see Fig. 4).

3.3. Differences in Cows' behaviour during trips according to the time spent and the space allowed in the outdoor area

3.3.1. During go-out trip

In the Winter trial, the Trip Speed dimension had no significant effect for time ($F_{1,41} = 0.59$; P = 0.45; Table 3), space ($F_{3,38} = 0.14$; P = 0.93) or for their interaction ($F_{7,34} = 1.43$; P = 0.26). The results were similar for the Stop Quality dimension as well (time: $F_{1,41} = 0.18$; P = 0.68; space: $F_{3,38} = 0.92$; P = 0.44; time x space: $F_{7,34} = 0.19$; P = 0.90;

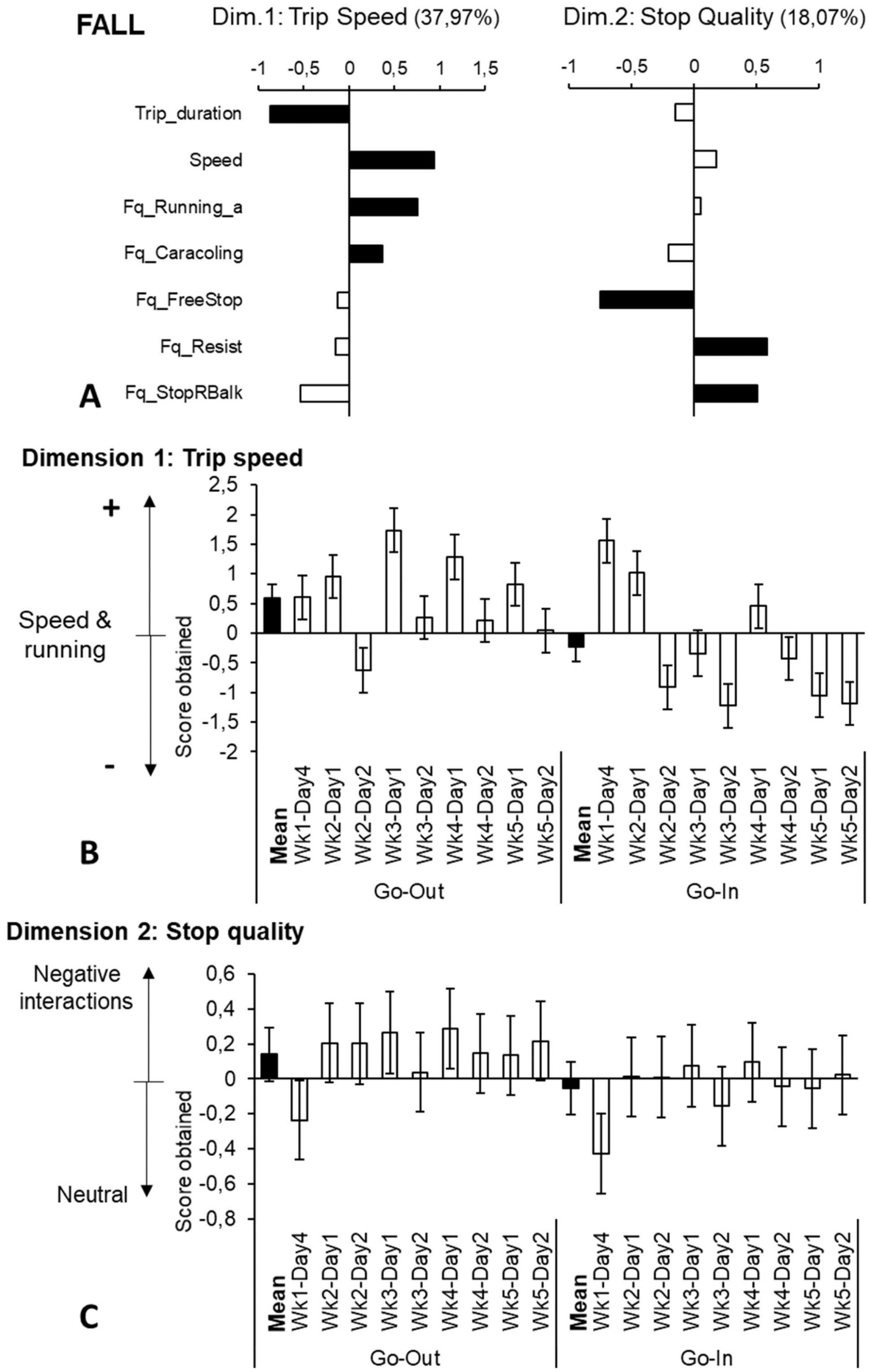

Fig. 2. Detailed results of the PCA conducted for the Fallr trial. A: Contribution of individual behavioral variables (measures) to the dimensions 1 (Trip Speed) and 2 (Stop Quality) of the PCA; B: Estimated means of the LMr of cows' scores on the Trip Speed dimension for the go-out and go-in trips; C: Estimated means of the LMr of the cows' scores on the Stop Quality dimension for the go-out and go-in trips. Mean (black bars on B and C)= Estimated mean of all weeks of each trip, In and Out.

Table 4) (see details in supplementary results).

In the Summer trial, the Trip Speed dimension revealed no significant effect for time ($F_{1,96} = 0.02$; $P = 0.88$; Table 3), space ($F_{3,93} = 0.46$; $P = 0.71$) or for their interaction ($F_{7,89} = 0.22$; $P = 0.88$). The Stop Quality dimension had no significant effect for time ($F_{1,96} = 0.07$; $P = 0.79$; Table 4) or for the interaction of time x space ($F_{7,89} = 0.61$; $P = 0.61$), but the effect of space was significant ($F_{3,93} = 6.38$; $P < 0.001$): cows in the 20 m^2 space had more negative interactions with handlers than in the other, larger spaces (Tukey comparisons: 20 m^2–40 m^2 $P = 0.002$; 20 m^2–60 m^2 $P < 0.001$; 20 m^2–80 m^2 $P = 0.01$). Detailed results (mean and SE) by time and size can be found in additional results.

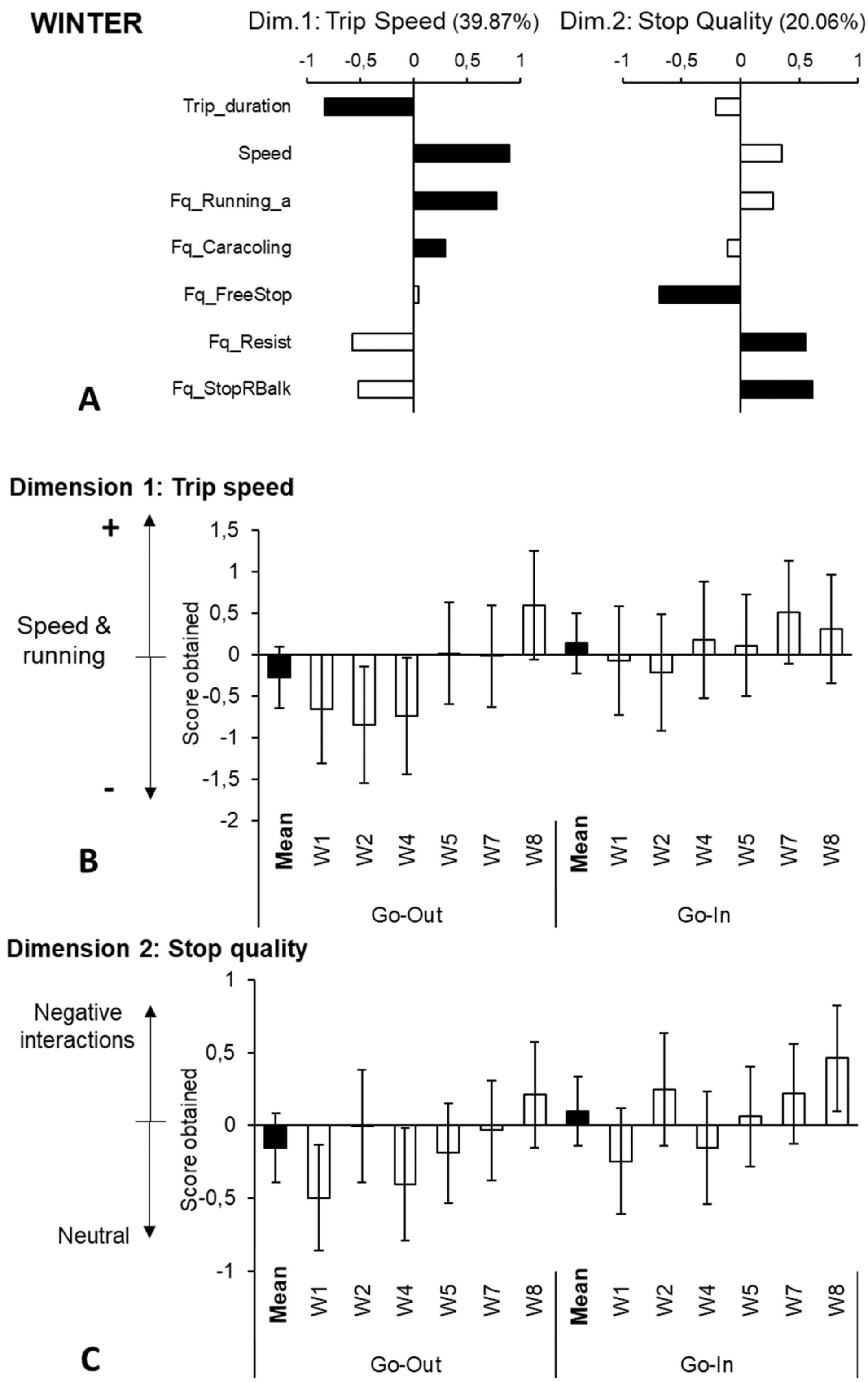

Fig. 3. Detailed results of the PCA conducted for the Winter trial. A: Contribution of individual behavioral variables (measures) to the dimensions 1 (Trip Speed) and 2 (Stop Quality) of the PCA; B: Estimated means of the LMr of cows' scores on the Trip Speed dimension for the go-out and go-in trips; C: Estimated means of the LMr of the cows' scores on the Stop Quality dimension for the go-out and go-in trips. Mean (black bars on B and C)= Estimated mean of all weeks of each trip, In and Out.

3.3.2. During go-in trips

In the Winter trial, there was a significant effect of time in the Trip Speed dimension ($F_{1,41} = 6.99$; $P = 0.01$; Table 3): cows that are out for 2 h were faster to go-in than after 1 h. There was no significant effect for space ($F_{3,38} = 1.45$;$P = 0.25$) or for the time x space interaction ($F_{7,34} = 0.60$; $P = 0.62$). Neither one of the time and space effects turned significant for the Stop Quality dimension (time: $F_{1,41} = 0.01$; $P = 0.93$; space: $F_{3,38} = 0.63$; $P = 0.60$; time x space: $F_{7,34} = 0.90$; $P = 0.46$; Table 4).

In the Summer trial, there was a significant time effect for the Trip Speed dimension ($F_{1,101} = 9.26$; $P = 0.003$; Table 3): cows that went out for two hours were faster to go-in than cows that went out for one hour.

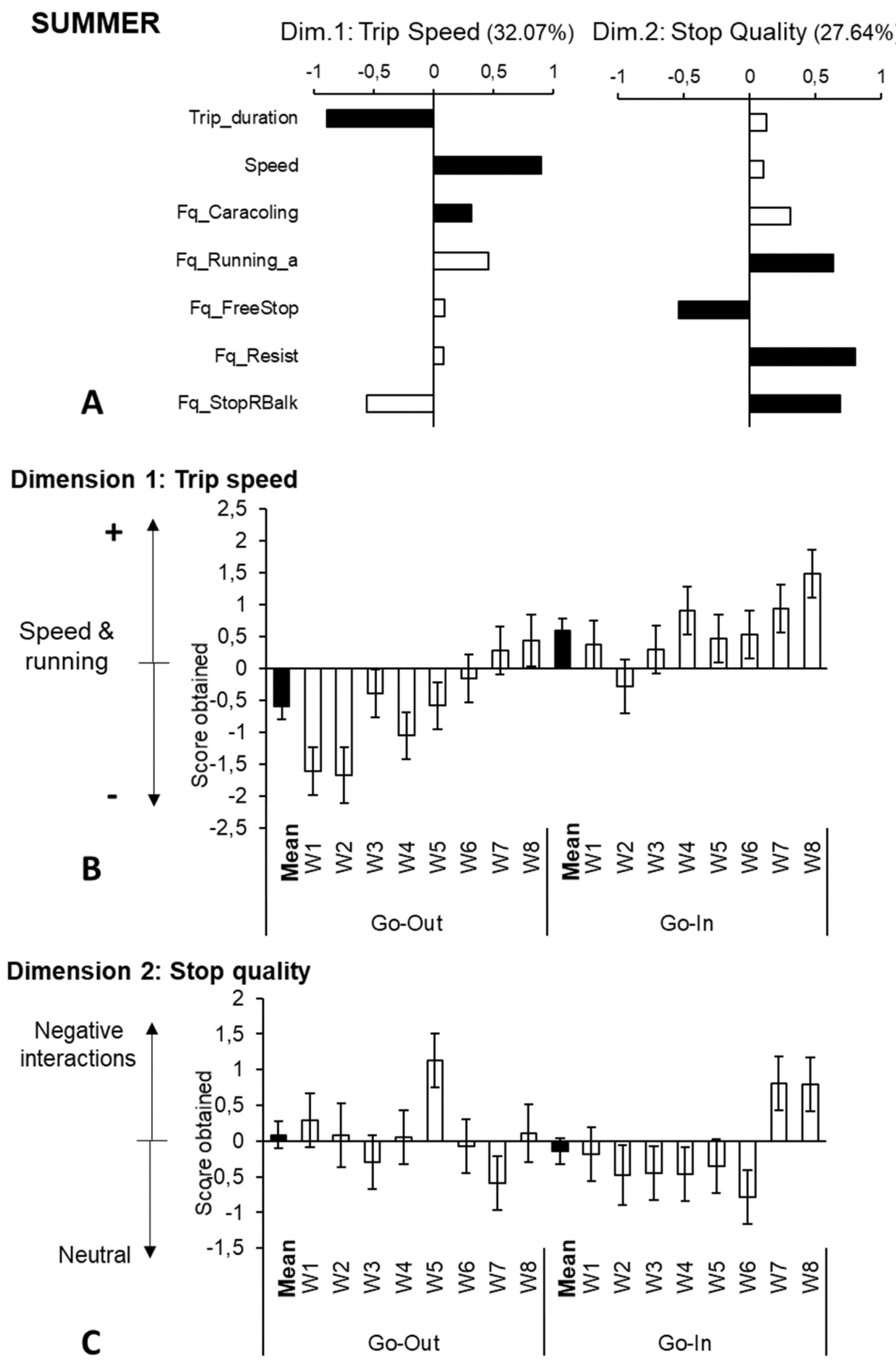

Fig. 4. Detailed results of the PCA conducted for the Summer trial. A: Contribution of individual behavioral variables (measures) to the dimensions 1 (Trip Speed) and 2 (Stop Quality) of the PCA; B: Estimated means of the LMr of cows' scores on the Trip Speed dimension for the go-out and go-in trips; C: Estimated means of the LMr of the cows' scores on the Stop Quality dimension for the go-out and go-in trips. Mean (black bars on B and C)= Estimated mean of all weeks of each trip, In and Out.

Neither space ($F_{3,98} = 0.50$; $P = 0.69$) nor the interaction of time x space ($F_{7,94} = 0.93$; $P = 0.43$) turned out significant. For the Stop Quality dimension, there was no significant effect for time ($F_{1,101} = 2.55$; $P = 0.12$; Table 4) or for the interaction of time x space ($F_{7,94} = 0.37$; $P = 0.77$). Space was revealed to be significant ($F_{3,98} = 4.10$; $P = 0.009$): cows in the 20 m^2 space had more negative interactions with handlers than cows in 60–80 m^2 spaces (Tukey comparisons: 20 m^2–60 m^2 $P = 0.01$; 20 m^2–80 m^2 $P = 0.02$). Detailed results (mean and SE) by time and size can be found in additional results.

4. Discussion

4.1. Points regarding the method

There were differences between the three trials in the speed of go-in and go-out trips. These differences reveal a variability in this measure

Table 3
Estimated means of individuals' coordinates (mean ± SE)[1] according time (all sizes confound) obtained on the PCA dimensions for the go-out and go-in trips for the Winter and Summer trials.

Winter	Time	Dimension 1: Trip Speed	Dimension 2: Stop quality
Go-out	1 h	-0.486 ± 0.463	-0.155 ± 0.257
	2 h	0.009 ± 0.456	-0.096 ± 0.256
Go-in	1 h	**-0.365 ± 0.482[a]**	0.071 ± 0.313
	2 h	**0.638 ± 0.475[b]**	0.067 ± 0.310
Summer			
Go-out	1 h	-0.569 ± 0.419	0.113 ± 0.229
	2 h	-0.577 ± 0.414	0.154 ± 0.223
Go-in	1 h	**0.237 ± 0.242[a]**	-0.352 ± 0.227
	2 h	**0.943 ± 0.237[b]**	0.168 ± 0.222

[1] Estimated means with different superscripts within a column for each trip (a,b) differ ($P < 0.05$)

Table 4
Estimated means of individuals' coordinates (mean ± SE)[1]according paddock size (all times confound) obtained on the PCA dimensions for the go-out and go-in trips for the Winter and Summer trials.

Winter	Paddock size	Dimension 1 Trip speed	Dimension 2: Stop quality
Go-out	20 m^2	-0.158 ± 0559	-0.518 ± 0.348
	40 m^2	-0.657 ± 0585	0.153 ± 0.370
	60 m^2	-0.088 ± 0.553	0.165 ± 0.347
	80 m^2	-0.051 ± 0.580	-0.303 ± 0.370
Go-in	20 m^2	0.367 ± 0.544	-0.182 ± 0.409
	40 m^2	0.032 ± 0.561	-0.029 ± 0.434
	60 m^2	0.582 ± 0.538	0.549 ± 0.407
	80 m^2	-0.436 ± 0.556	-0.062 ± 0.432
Summer			
Go-out	20 m^2	-0.514 ± 0.471	**1.049 ± 0.295[x]**
	40 m^2	-0.383 ± 0.455	-0.232 ± 0.276[y]
	60 m^2	-0.794 ± 0.448	-0.294 ± 0.268[y]
	80 m^2	-0.602 ± 0.459	-0.010 ± 0.281[y]
Go-in	20 m^2	0.803 ± 0.298	**0.725 ± 0.311[x]**
	40 m^2	0.573 ± 0.287	-0.106 ± 0.295[xy]
	60 m^2	0.402 ± 0.277	-0.507 ± 0.285[y]
	80 m^2	0.582 ± 0.295	-0.480 ± 0.306[y]

[1] Estimated means with different superscripts within a column for each trip (x,y) differ ($P < 0.05$)

which allows us to identify a possible difference between treatments or individuals. In each trial, cows exhibited a greater travel time on go-out than on go-in trips during the first one to two days of exit, so during the habituation period. The outing and the outdoor access are considered as novelty for all animals, as these were their first experiences in the exercise area and their first outings in those conditions. The outside is an unpredictable environment with many complex stimuli that stimulate exploration and curiosity, or even vigilance (Berlyne, 1955). Animals take time to explore and analyze novel environments or items they are faced with (Zhang et al., 2021). This novelty effect translates into lower speeds, with or without stops. However, these stops are of short duration (the animal is not blocked/ does not refuse to move forward) and are not due to handler restrictions. When studying raw motivation, these novel effects should be taken into account and not neglected in the interpretation: the relatively low speed during these first days does not necessarily reflect a lack of motivation but rather a time of discovery and/or learning by the animal.

In the experimental days that followed habituation, however, trip time was generally reduced and the same behavioural axes emerged from the different PCAs in each trial, showcasing the observed measurements' repeatability although different animals and modalities were used. The first axis illustrates the speed of the animals in connection with running and caracoling behaviours. The second axis illustrates the quality of the stops done by the cows, with on one end, the cows deciding to resume locomotion on their own, and on the other end of the axis, the animals stopping without resuming on their own, or trying to force their way or to turn around, resulting in negative interactions with the handlers. Although the speed of a trip has already been used to measure the motivation to go in an open-field (Veissier et al., 2008), our work of associating this measure with additional behavioural variables which illustrate the cow's experience during the trips helps us to better understand their motivation to complete the trips. In our study this motivation seems to vary according to different factors.

4.2. Motivational profiles

Past the novelty of the first days, we observed differences between trials in the evolution of trip speed and of the quality of the stops. In the Winter trial, the animals no longer showed differences in speed between go-out and go-in trips, whereas in the Fall trial, go-out trip speeds were faster than go-in trip speeds, and vice versa in the Summer trial. These differences in speed are accompanied by behavioural differences related to locomotion and interactions with handlers. All of these differences have allowed us to draw motivational profiles that seem to vary according to different factors, and which serve to illustrate how the behaviour of the whole group of cows enrolled in each trial evolved over the course of the different trials.

In the Winter trial, a "Mile-a-minute" profile developed and is characterized by a decrease in the go-out travel time during habituation, followed by a stabilization which resulted in no difference between go-out and go-in trips. No increase in negative interactions with the handlers, with either stops or attempts to turn back, was observed. This profile exhibited a similar motivation during both trips, and which was maintained over the course of the trial. The "Thwarted motivation" profile emerged during the Summer trial, and was characterized by, after a rapid decrease, a notable increase in travel times on go-out compared to go-in trips following a temporary increase of the restrictions imposed by human handlers. These cows also exhibited more negative behavioural interactions with handlers, such as forced stops, resistance, and attempts to force their way through, which can potentially be attributed to an increase in frustration. The "Outdoor enthusiasts" profile was observed in the Fall trial, and corresponds to a combination of rapid go-out trips with a greater occurrence of behaviours such as caracoling and running during those trips, while go-in trips back to the barn had reduced travel speed.

"Mile-a-minute" cows appeared to be motivated both on the way out and on the way back, compared to "Outdoor enthusiasts" which seemed motivated and expressed joy in the form of behaviours such as caracoling and running upon accessing the outdoor exercise yard, while being less motivated to return to the barn. There are several elements hypothesized to be in cause in the behavioural expression for those two motivation profiles, weather being one of these. Although previous studies have shown that cows with previous experience to the outdoor conditions choose to go outside even in harsh winter conditions (Shepley et al., 2016), the cows in our trials were not previously habituated to experience outdoor conditions specific to winter such as cold air temperatures, precipitation, and wind. Although dairy cows are able to tolerate very cold conditions due to the considerable amounts of heat generated through their metabolic processes, they remain sensitive to the outdoor conditions, which may impact their experience of the outdoor access, especially when no other resources such as food or shelter are provided, as was the case in our trials. Thus, we cannot exclude the possibility that the weather conditions during the Winter trial may have led our cows to look forward to returning indoors more so than Fall trial cows. Their motivation to access the outdoor exercise yard may have been compounded with a greater motivation to head back once their needs for movement and social interactions among other things had been satisfied. The cold could also act as a confounding factor on our measure of motivation: engaging in physical activity represents one way to generate body heat (Brouček et al., 1991; Webster et al., 2008), and it is possible that cows facing cold conditions may have decided to move faster as a means to generate more heat rather than due to a specific motivation to return from the exercise yard. Winter conditions may have also affected the ground surface in the corridor and in the paddocks, despite efforts to maintain good traction in both settings. This could also have made the cows more cautious, limiting their speed when they would have been motivated to go faster in the corridor, and reducing their movement in the paddocks (Telezhenko and Bergsten, 2005). This combination of factors could lead to cows being more motivated to move during the trips, but moving only at the maximum speed comfortable for them given the ground conditions in the corridor. Fall trial conditions therefore may have allowed the cows to better express their motivation for outdoor exercise access.

The data we collected on trips brings light on the factors which likely contributed to the development of the "Thwarted Motivation" profile; being very excited from the start, these cows faced considerable restrictions to their movement, specifically in the corridor, where handlers would sometimes go as far as stopping them during the habituation phase, in attempts to quell the high level of excitement they exhibited. During the habituation phase, additional handlers had to be put in place and handling was adapted to the cows' behaviour during the outing. Although forced stops were implemented only on the 7th and 8th days of habituation, the increase in trip duration we observed remained throughout the experiment, showing that their motivation was affected on a lasting basis. Forced stops were likely perceived very negatively by the animals, especially by the most excited individuals, and negative events are known to have a lasting and stronger effect on animals than positive events (Taylor, 1991). In addition, cows are sensitive to the way they are handled and able to recognize and associate a particular person with a particular treatment (de Passillé et al., 1996; Munksgaard et al., 1997; Waiblinger et al., 2002). Since the handlers remained the same throughout the entire Summer trial, it may have maintained the mistrust of the animals during the outings. In contrast, the positioning of the handlers in the Fall trial was further away from the cows, and did not appear to lead to a decrease in motivation. "Thwarted motivation" cows also expressed negative interactions with handlers, with no consistent effect of time: there were days where more of such interactions were observed, an effect we can attribute to the way the handlers' actions and positions were tailored to the cows' behaviour during the previous and the current outings. Indeed, we could observe a co-occurrence of negative interactions and instances of running; handlers attempted to stop the cows from running, resulting in negative interactions, with cows sometimes attempting to force their passage through the handlers due to their motivation for moving faster (Hemsworth and Coleman, 2011). These instances can thus be considered as the expression of frustration due to an unfulfilled motivation to move forward.

4.3. Outdoor access conditions impact the Animal's motivation

After two hours, cows returned indoor more quickly than after 1 h. For all trials, the exercise area consisted of a set of paddocks set-up within a single natural surface area, and represented a relatively bare area with regards to the amount of resources available. Thus, since no resources were supplied in the exercise yard in terms of no feed, water, or shelter – all resources readily available indoors – provided to the cows during the exercise access period, a period of time in the day during which cows were not used to being without food. In conditions where animals have to make choices between resources offered in their housing, feeding was found to be a primary need that takes precedence over secondary needs such as a dust bath in hens (Petherick et al., 1993) or space after a confinement (Jensen et al., 1998). The absence of water and shelter may also have led to cows being more exposed to either cold (Winter) or hot (Summer) conditions. Cows modify their behaviour when thermal conditions fall outside their range of comfort. In hot weather, cows on pasture were observed to drink more often when no shade was provided (Palacio et al., 2015), whereas when continuously exposed to cold, they ate more (Brouček et al., 1991). The absence of these resources in the paddocks could thus explain why cows, after a time longer than 1 h, were more motivated to return to the shelter- and food-providing barn environment, regardless of the season. Providing paddocks furnished with these resources may have eliminated the difference in the cows' motivation to return after 1 vs 2 h.

When going out or returning in from the smallest paddock (20 m^2) in the summer trial, cows interacted more negatively with handlers compared to the other paddocks. This effect was only found in the Summer trial, and was probably partly due to the season: higher temperatures were found to cause animals to be more active and excited (Belgrad et al., 2017; Brzozowska et al., 2014). The fact that, by their presence only, cows occupied nearly 30% of the 20 m^2 allowed in these small paddocks highlights how small a space this represents for two cows, and these dimensions obviously limited their opportunities for movement and locomotion, leading to frustration. This reality was reflected in our results, with cows seemingly not wanting to go to and to stay in these very small paddocks; keeping captive animals in a restricted space can cause frustration and potentially lead to stress upon longer-term or more frequent exposure (Morgan and Tromborg, 2007). Moreover, the attempts from these cows to run and force their way through may represent a form of locomotor rebound, which was previously observed in animals deprived from opportunities to move or to exercise (cattle: Jensen, 1999, Loberg et al., 2004; horses: Houpt. et al., 2001, Freire et al., 2010). Additional frustration may also arise in the cows due to the social component of the exercise access process. The space requirements for group animals extend beyond what is needed only for locomotor purposes, and are more complex due to the presence of social interactions (Petherick 2007). Such interactions require the ability to move away and put distance between the two protagonists in order for the interaction to come to an end, which is greatly limited in the smaller paddocks. This may have further increased the frustration and aggressiveness of the individuals which would finally be expressed upon leaving the paddocks.

4.4. Limitations of study

Our study allowed us to observe the motivation of an animal to obtain an enrichment (in this case outdoor access). Our study focused on a limited number of individuals and saw a high degree of individual variability within the same trial: some animals were highly motivated while others were much less so. It would therefore would need to be repeated on more individuals in a larger number of contexts in order to strengthen our conclusions. In addition, the trials spread across three different seasons, and while the trip times were reliable indicators of motivation in most cases, there were certain environmental factors (snow in winter, mud in fall, heat in summer), that may have extended trip speed, despite not necessarily having an effect on motivation. It is for this reason that the most motivated individuals could only be compared within trial, as the trip speeds differed between trials (hence our focus on motivational profiles rather than individual measures between trials). Future studies that would want to build on this research would thus have to ensure standardized locomotion conditions between trials, beyond the simple distance/orientation of the hallway.

5. Conclusion

Animal emotions are very difficult to analyze. Our study tested a novel method of evaluating cow motivation to access an enrichment. The duration of trips to and from an exercise yard, combined with observations of the behaviours conducted by animals during these trips, can allow for an effective evaluation of their motivation. The motivation of movement-restricted animals to access an exercise yard appears to be affected by various factors directly or indirectly related to the outing process. Such factors include the duration of outdoor access and the size of the paddock provided, with our results showing that cows are less motivated for outdoor access longer than 1 h when no feed, water nor shelter are provided, regardless of the season. Additionally, we found that smaller exercise yardslimit their behaviours and may become a source of frustration which will, in turn, impact their motivation. Finally, we found that restrictive handling of the animals during the outing process can negatively impact their motivation and lead to frustration, as showed by the different motivation profiles we observed during the trials conducted for this study.

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Data availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.beproc.2023.104957.

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