“Balance index (IB) for group behaviors” – a mathematical way for finding “where is the trouble”

„*All the so called spells in fact are only question of balance. To be a good witch you have to become the central stable point in the middle of moving see-saw.“*
By Sir Terry Prachet, The Discworld Series

When training zoo-animals in groups, the effort of every individual is influenced by relationships inside that group. As trainers, this can be difficult to understand objectively, which can impact our success with the animals. To set the animals up to succeed, we need to appreciate them as a part of a group, and monitor their individual successes. To assist us to do this, we have generated a mathematical formula.

In Prague Zoo we have trained a group of Ring-Tailed Lemurs to participate in a show. The show is presented by one person and number of animals changes from 8 to 11. The hierarchical structure of the animals is dynamic and their actual relationships strongly influence training and participation of each individual. To enable us to objectively assess, what is going on the group, and hence continue to set them up to succeed, we have devised the following system:

The basic idea is, that for good training of any group it is necessary to maintain a “balance inside the group” for each behavior. That is why each animal in each behavior in the show is rated according using the following variables:

1) K - Does animal KNOW the behavior?

2) R - Expected REWARD

3) PA - POTENTIALl “to be ASSAULTED”.

4) D - DIFFICULTY (also control over resources).

The “Balance index (IB)”, which speaks about the probability that the behavior is running t the moment, we count as $IB = (K \times R)/(PA \times D)$, because we expect, that the K and R make the probability higher and PA and D lower. The actual levels of IB for each animal gave us the basic information about balance inside the group. We found, that this model developed on lemurs could be successfully used on other species and animal groups we train and it can solve many troubles.

How to calculate the IB ?

We assign for each behavior to each animal the numeral value of the following variables. For each animal we assign it only for the behaviors we actually ask at the moment. For example if we want one animal to jump and the rest of the group just to sit and wait, we assign values of variables for “jumping” for one and for “sitting” for the rest of group.

1 variable: K - Does animal KNOW the behavior?

0 – does not know at all
1 –it knows only some basic steps
2 – it knows the full behavior, but not under stimulus control
3 – the desired behavior is under stimulus control

Variable 2 - R (expected REWARD) – the reward which is expected by the animal. Remember, the animal does not perform the behavior to reach the reward we really give but to reach the reward it expects to receive. It depends on the reinforcement schedule, reward used as the last one and many other variables.
0 –no reward
1 – food reward, but not the favorite one food
2 – ordinary food (ordinary used in normal daily feed ration, not in training)
3 – ordinary reward (not standard part of the daily feed ration, but the most frequesntly used during training
4 – “bonus” (like a “week jackpot”, for example a little more pieces of food used as rewards)
5 – „jackpot (extra big reward)
The value 4 or 5 we assign only when the animal has a good reason to expect it (for ex. because of reinforcement schedule) to expect them, not only when we are going to give it.

Variable 3 - PA – (Potential “to be ASSAULTED”)
For example the PA increases when submissive animal is located right under the branch where a dominant aggressive animal is sitting. For another species the PA is increasing for submissive animal for example when thinner sea lion is laying belly up on the bank when the dominant one animal is near. For hoofstock a high PA has the weaker individual inside small paddock when the dominant one is controlling the only escape way. All the values of those categories depend on trainers sense and knowing of the animal.

1 – no potential (animal stays in a safe position or it is the strongest in the group),
2 – the potential would be actual only when conditions will change (for example dominant primate sitting under the submissive one could be endangered only when his hierarchy will change
3 – actually exist, but small
4 – actually exist on high level
5 – actually “deadly endangered”

Variable 4 - D (difficulty, also control over resources)
How difficult is the behavior for the animal. This can be also understood as control over resources of food or their accessibility, because the behavior we feel as the way to reach the reward – to get control over it. For example when lemurs are sitting around the trainer, the highest level of D can be found by the animal sitting the nearest next to the pocket with rewards – the animal has the highest controll.
1 – no difficulty (high control)
2 – small difficulty (high, but not maximum control)
3 – middle (middle control)

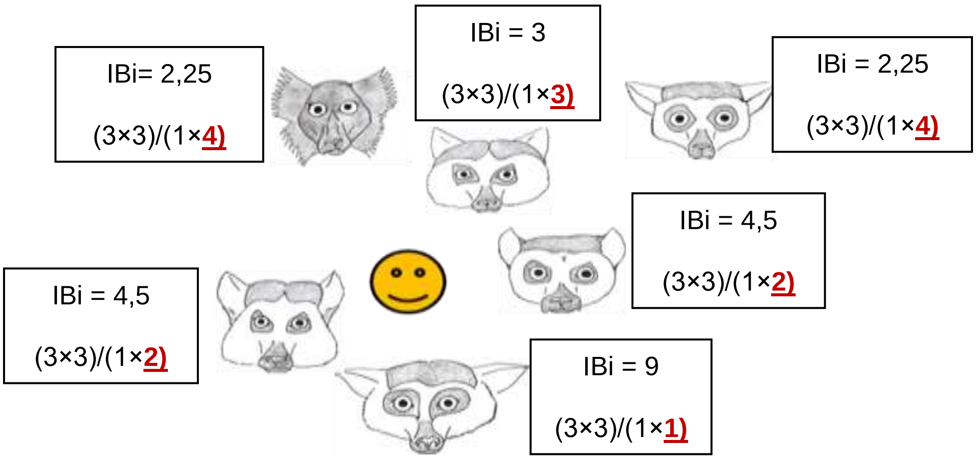
4 – high (small control)
5 – extremely high or impossible (no control over resources)

Because it is clear, that the K and R make the probability of succesfull behavior higher and PA and D lower, we calculate the IB from formula: **IB = (K×R)/(PA×D)**

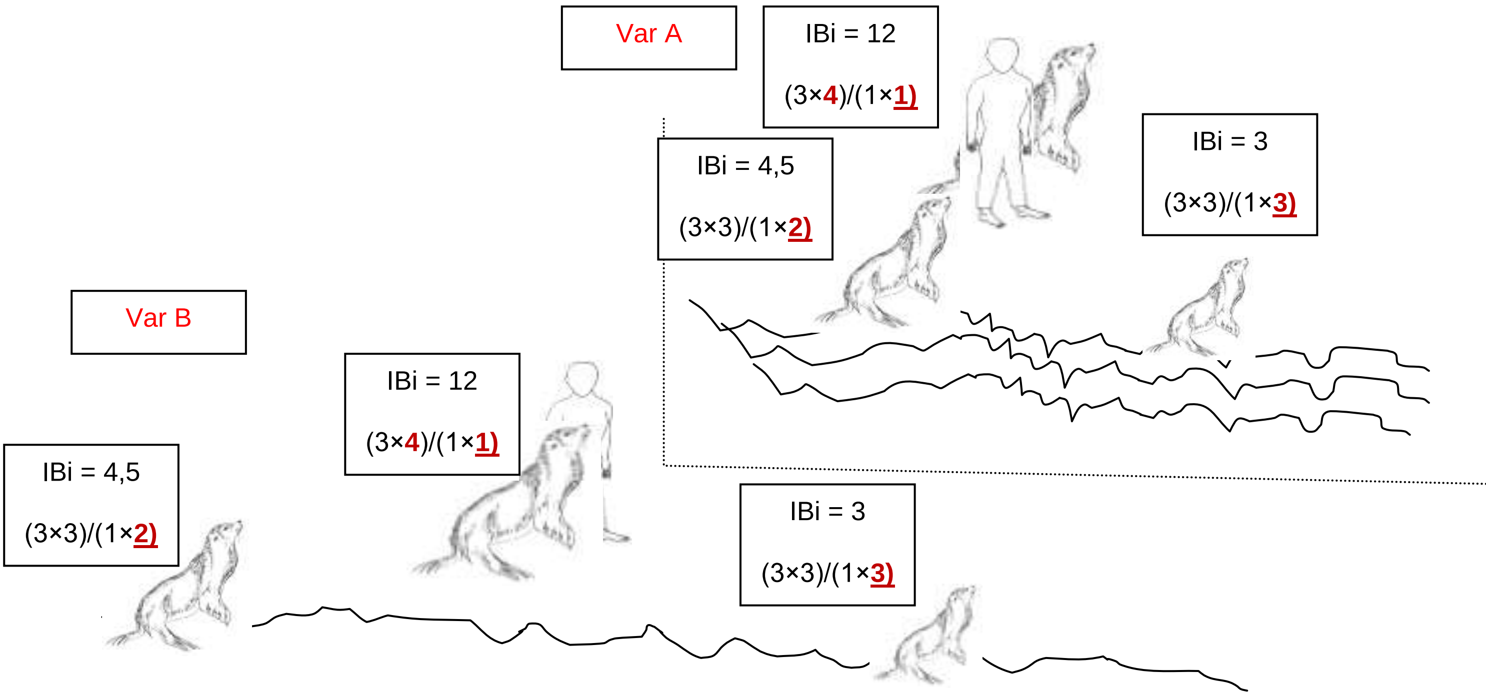
In every group we have to respect the hierarchy during training. Finally it means, that for positively trained group, where the trainers presence is understood by animals as a chance to reach reinforcer, the IB for the dominant animal must be the highest and then decreasing with lower hierarchy position of each individual. If the IB levels are decreasing according to hierarchy possition, the balance inside the group breaks down and the behavior of the group falls. This is logical, because the most dominant animal in the group has the right to get benefits, which could be expressed by amounts of food, but also as safety of it´s position, difficulty how to reach the food and many other variables, which are incorporated in our model.

When thinking about the whole situation from the viewpoint of the animal, we are commonly able to assign ideal values for every variable, which would ensure peace and balance inside the group. It means situation, when no one is endangered by the others, every animals cooperate and there is no flutter – it means the groups is well balanced. The IB of each individual in such a peaceful theoretical situation we can term as IBi – Balance index ideal.

<u>Example of ideal situation (IBi):</u>
<u>Action 1:</u> Lemur show in Prague Zoo
<u>Behavior:</u> „Basic positioning before the show" – each animal has to stay on it´s own basic position around the trainer.
<u>Rem.-</u> The basic lemurs positions are chosen so, that the most dominant aggressive animal is on the ground and the others are up to him on branches – the most submissive are the most highly and so they can feel safe (small PA). The most dominant animals are also located the most near the pocket with rewards – so they have the best control over resources (the smallest D)
<u>Calculation of</u> IBi (IB ideal): for every individuals K= 3 (they are all under stimulus control), R=3 (they do all maintain the behavior for ordinary rewards, no jacpots are needed), PA=1 (they all do feel safe thanks to their positions) a **D= 1 - 4** depends on **utility of every position (needs to hold by the thin branch/staying on the ground) and the distance from pocket with rewards (emoticon), which leads to different value of control over resources.** Thanks to this difference in D (difficulty) the IB is highest for the dominant and decreases with decreasing status in hierarchy – which ensures the balance in the group during this behavior.



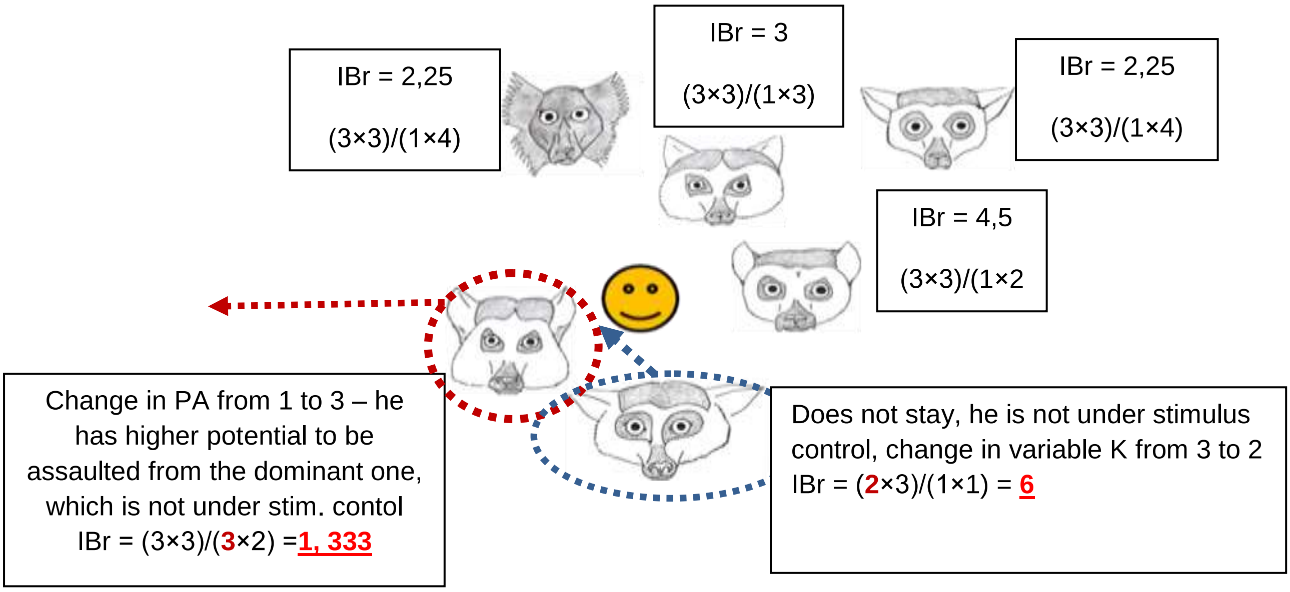
Example 2 – Basic possitions of three sea lions around the trainer (hypotetical example)
Rem.: The weakest animal has the position out of the reach of the dominant one. This weak animal is also located right on the bank by the water, because the water is the safe zone for him, where he can escape when endangered. The dominant animal has the biggest distance to the water, because it is the strongest in the group and not actually endangered by any group member – so it has no need to escape. The trainer, as the "rewards resource", stays nearest to the most dominant animal, which gives the sea lion the biggest control over the food resource. The trainer can also split up the first and the second sea lion in hierarchy, which prevents them from conflicts.
Calculation of IBi (IB ideal): For each individual K= 3 (everyone under stimulus control), **R= 3-4** (they all do work for ordinary reward, therefore the dominant one receives a little more to reinforce him for letting the others to participate) PA=1 (all of třhem do feel safe) a **D= 1 - 3 – although the difficulty is equal for every animal, the distance from trainer and so control over resources is different.**



But we all know that in praxis the situation many times is different from the ideal and so the IB values for each animal in the real are different IBi. Such a real situation we could call as
IBr (IB real)
Example of IBr:
<u>Action 1:</u> Lemur show in Prague Zoo

<u>Behavior:</u> „Basic positioning before the show“ – each animal has to stay on it´s own basic position around the trainer.

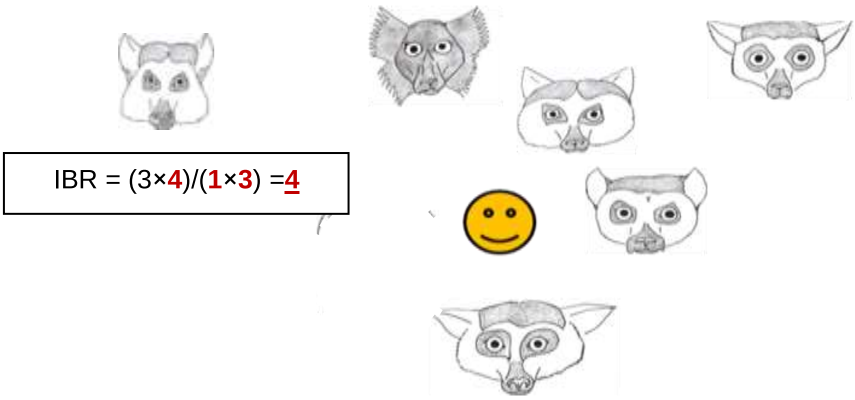
<u>Rem.:</u> The most dominant lemur (staying on the ground) is not fully under stimulus control and so he can somentimes jump up. It leads to the situation, when the animal second in hierarchy sits permanently out of the group, not at it´s basic possition. Allthough the trainer maybe does not se the change in IB of the first dominant one, he can see the change in the second one.



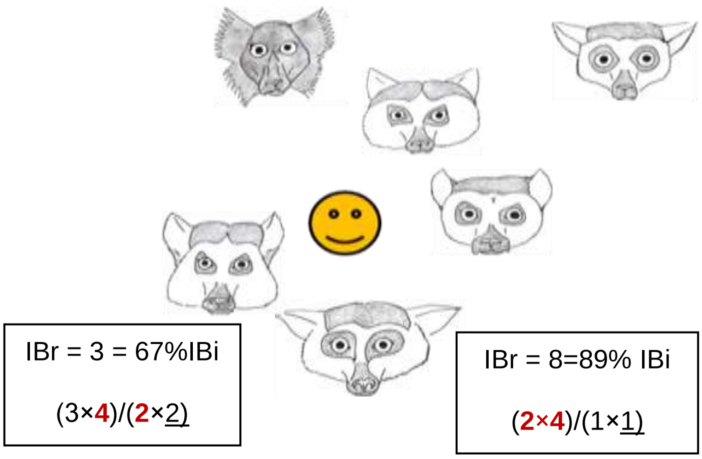
Although the IBr of the most dominant animal is not so much different from the ideal level (IBi) and so the animal still participates on the behavior (and the trainer maybe does not see any change), the IBr of the second animal felt to down (IBr ≤ IBi) and so the animal does not have enough motivation to stay in the behavior. See, how just a small change in IB of the dominant animal (IBr =67% of IBi) could lead to much biger change in the lower hierarchialy posted animal (IBr =30% of IBi). This model practically shows, how the success of the group behavior stays and falls with control over the dominant animal and every small changes on this control leads to bigger changes on the other members.

How to solve the situation?
1) – The trainer can change all the beahavior, resp. to change the basic position of the second lemur, which will lead to lower PA (the animal is more safe), although it will probably a little increase the difficulty resp. decrease the control over resources (higher D) so the trainer

would probably have to increase the R (expected reward) by more intermittent schedule, maybe to give some jackpot. The final IBr of this individual will grow back to 89 % of IBi, high enough to make the animal sit at this new place. The animal is also far enough from the rest of group not to decrease their feeling of safety (PA)



2) – The trainer will not change the basic positions, but he will focus more on the dominant animal (going back to kindergarten – leads to better K variable; higher expectation of rewards by intermittent schedule – makes higher R) . The increase of IBr on the dominant on will lead to better control over him and so better feeling of safety of the second lemur (lower PA). The trainer can also make higher R of the second animal by some jackpots and so make the IBr higher.



This mathematical model gives us following information about our lemur show:
1) Every behaviors of each animal have to be understood as a part of a complex group behavior, when we train all the group, not only one individual.
2) This group behavior stays and falls with the control over dominant member and every small, almost not significant, changes in control over dominant animal would lead to bigger changes in subordinant members of the group. When seeing a trouble in behavior of any subordinant lemur, many times this is caused by lost of our control over the dominant animal.
3) To have a well balanced group behavior IB has to be the highest for the dominant animal and decrease for the rest of group with their decreasing hierarchy status. If the IB for

subordinant animal is higher then for the dominant one, this will probably lead to fall down of the group behavior.
4) We can establish 4 variables directly influencing success of each behavior, where two of them (K, R) increase and two (PA, D) decrease the probability that the behavior of each animal will run at the moment. Two of them (K, D) are also specific for each behavior in the show, but other two (R, PA) are more specific for the animal then for the behavior. That is why the actual value of R and PA will influence every behaviors of the one concrete animal during all the show.
5) All the actual values of those variables for each animal we can simply identify from a group behavior, where the highest number of group members can participate in one moment (we say the behavior has "the highest capacity"). For example when positioning lemurs around trainer there is capacity about 6 participating animals in one moment, but for example for "selfclosing" inside the transport box there is a capacity only 1animal.

This all together gave us information how to solve the show: The first behavior we ask the lemurs has to be the one with the highest capacity (basic positioning around the trainer). From success of each animal in this behavior we can identify if there are any hidden troubles inside the group, resp. what are actual values of K, R, PA and D. And because we know, that K (does the animal know?) and D (difficulty) are specific for each behavior and R (expected reward) and PA (potential to be assaulted, feeling of safety) are specific for each animal and can dynamically change, we will improve them during the show to make the final IBr for each animal for each behavior as high as possible (ideally equal to IBi), to ensure that the behaviors will successfully run.
For example, if we see during the first behavior "positioning", that the second animal in hierarchy is probably afraid (higher PA) of the first one, in the rest of behaviors in the show we will try to increase his R (by jacpots and intermittent schedule), we will not ask for behaviors where the PA can potentially grow up (for example hanging on the branch head down) and we will focus on the dominant lemur to increase the control over it´s behaviors for example by "going back to kindergarten" technique.

We have found, that this mathematical model fits not only on lemurs, but can be successfully used on other species in the zoo when trying to find out hidden troubles and motivation in the group. It gave us answer how to manage mares of Przewalskii horses when training to split them up and stay alone inside small stalls , when training female of Pere´s David Dear to go inside small paddock and other examples. This also helped to the keepers from other zoos to manage their sea lions during the show or to scientists working with experimental macaques to manage the group during training.

In fact, in most of the cases the keeper or trainer does not have to calculate all the model. In most of situations the trainer finds very quickly that he focused just for one animal and forgot to work with the rest of group, many times that IBr for dominant animal in the group is lower then for the submissive and that he has to improve the balance. And that is why we developed the model. If the trainers will use it, they have to think about the situation from viewpoint of

all the group. This is the way, how trainers by themselves will find the troubles without our assistance. This model makes them to understand, that:
„*All the ~~so called spells~~ GROUP TRAININGS in fact are only question of balance. To be a good ~~witch~~ TRAINER you have to become the central stable point in the middle of moving see-saw.*“

The video from our lemur show you can find at www.zoopraha,cz/en

Any ideas you can send to the address:

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