How does variation in corticosterone relate to animal personality?

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Författare
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Abstract
Animal personality is a fairly new branch of biology and has been defined as a difference in behaviour between individuals that is relatively consistent across time and/or context. What researchers now are interested in is to find out what it is that creates and maintains this relatively consistent difference between individuals. One possibility is the stress hormone, corticosterone. I have in this report summed up some of the available studies regarding animal personality and its possible correlation to corticosterone. The personality traits that have been reviewed in this report are boldness, exploration, activity, aggressiveness and sociability. The result of these studies show that boldness have both a negative and a positive correlation; exploration showed different correlations between studies; aggressiveness showed different correlation between different animal types and sociability showed both a negative and none correlations. The only one that I could not determent the correlation for was activity. The research regarding animal personality and corticosterone can be of use when looking at animal welfare and how stress affects different individuals. This can give us a direction in our work to reduce stress for animals in research facilities and food production.

Nyckelord
animal personality, correlation, corticosterone, HPA axis, personality traits, stress
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1 Abstract
Animal personality is a fairly new branch of biology and has been defined as a difference in behaviour between individuals that is relatively consistent across time and/or context. What researchers now are interested in is to find out what it is that creates and maintains this relatively consistent difference between individuals. One possibility is the stress hormone, corticosterone. I have in this report summed up some of the available studies regarding animal personality and its possible correlation to corticosterone. The personality traits that have been reviewed in this report are boldness, exploration, activity, aggressiveness and sociability. The result of these studies show that boldness have both a negative and a positive correlation; exploration showed different correlations between studies; aggressiveness showed different correlation between different animal types and sociability showed both a negative and no correlation. The only one that I could not determine the correlation for was activity. The research regarding animal personality and corticosterone can be of use when looking at animal welfare and how stress affects different individuals. This can give us a direction in our work to reduce stress for animals in research facilities and food production.

2 Introduction
If you would to ask a pet owner if their pet has a personality most of them will say yes, and they may be right. Recent studies that have investigated animal personalities have shown that animals indeed have personalities (Carere & Maestripieri 2013). For a long time, biologists have seen that there is diversity in nature between individuals in their way to handle different situations. Biologists are now wondering what it is that causes the variation between individuals in the same population when it comes to behaviour (Gosling 2001). However, animal personality is a fairly new research field within biology and therefore it has a lot of unanswered questions (Gosling 2001).

Animal personality
Animal personality is defined as a difference in behaviour between individuals that is relatively consistent across time and/or context (Dall et al. 2004). These differences between individuals can be found in several different species, from insects to vertebrates (Gosling 2001). One of the major difficulties when investigating animal personality has been that there is no universal scale when investigating personality traits (Pervin and John 1999). I will in this study use the five personality gradients
described by Réale and colleges (2007). These five gradients have been used by several researchers and the categorization is well described. These five gradients are boldness, exploration, activity, aggressiveness and sociability (Table 1, Réale et al. 2007).

Table 1. The description of the five personality gradients according to Réale et al. (2007)

<table>
<thead>
<tr>
<th>Personality gradients</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boldness</td>
<td>How an individual reacts to a situation that can be risky but not new to the individual.</td>
</tr>
<tr>
<td>Exploration</td>
<td>How an individual reacts to a new situation or object.</td>
</tr>
<tr>
<td>Activity</td>
<td>An individual’s activity in a situation that is neither risky nor new.</td>
</tr>
<tr>
<td>Aggressiveness</td>
<td>A confrontational reaction towards conspecifics.</td>
</tr>
<tr>
<td>Sociability</td>
<td>How an individual reacts in social situations or when being held from its conspecifics.</td>
</tr>
</tbody>
</table>

The knowledge on why animals seem to react in different ways when experiencing similar situations can be used when improving animal welfare and health (Caivgelli 2005; Boissy & Erhard 2014). By knowing how individuals with different animal personality behave, farmers and researchers can adjust the housing and environment for the animals to decrease health problems and injuries that can occur when animals are living with imperfect conditions (Boissy and Erhard 2014).

What is interesting for researchers to discover now is what it is that creates the variation when it comes to animal personality (Dall et al. 2004). One approach researchers are investigating is if there is an underlying proximate mechanism that is correlated with an individual´s behavioural response.

**Stress and corticosterone**

One proximate underlying mechanism that might be related to variation in animal personality is the stress response, which includes the release of
corticosterone (cortisol in some species, such as fish and most mammals). For an individual to be stressed it has to be exposed to a stressor that can be considered threatening for the individual (Cockrem 2013a). Stressors can be divided into emotional or physical stressors (Cockrem 2013a).

When an individual is exposed to some sort of stressor it will initiate a stress response in the body, comprised of endocrine, nervous and immune responses (Charmandari et al. 2005). The main stress response is called the hypothalamo-pituitary-adrenal (HPA) axis. This starts within seconds after encountering the stressor (Sapolsky et al. 2000). The first action is the activation of the hypothalamus in the brain, which is the start of a series of steps that ends with the secretion of corticosterone (Figure 1).

**Figure 1. Stress response by the hypothalamo-pituitary-adrenal axis (HPA axis).** It starts with corticotropin-releasing factor (CRF) from the hypothalamus. The CRF then activates the release of adrenocorticotropic hormone (ACTH) from the pituitary gland. ACTH reaches the cortex of the adrenal gland, which then releases corticosterone (CORT) out into the blood system.

When an individual feels stressed, both behavioural and physical adaptation starts in the body. Some of these adaptations can be that the individual becomes more aware of its surroundings (behavioural
adaptation) or increasing circulation of oxygen and nutrients in the body (physical adaptation) (Charmandari et al. 2005).

Animal personality and corticosterone

Researchers know that animal personality is different between individuals and that the level of secreted corticosterone when stressed also differs between individuals. Some researchers try to connect animal personality and corticosterone levels by using the term ‘coping styles’, which tries to explain how individuals with different animal personalities cope with stress (Koolhaas et al. 1999; Cockrem 2013a). When the term ‘coping style’ is used in studies, the researchers refer to an individual’s coping strategy when it comes to stress. The general idea is that individuals that are bolder, more aggressive and more active use a proactive strategy when coping with stress. These individuals also seem to display low corticosterone levels during these situations. The opposite of proactive is called reactive and displays high levels of corticosterone.

This literature study will be limited to rats and different species of birds because I will only use studies that have looked at corticosterone and animal personality traits. In this literature study I will discuss animal personality traits described by Réale and colleagues (2007; table 1) and if there is a correlation to corticosterone and which direction the correlation might take. I will also discuss where I think more research is needed in the terms of animal personalities and corticosterone.

3 Discussion
Table 2. A short summary of some studies comparing personality traits and corticosterone in birds and rats. The rat lines used in the studies are Flinders Sensitive Line (FSL), Sprague-Dawley (SD), Wistar-Kyoto (WKY), Carioca High freezing (CHF), Carioca Low Freezing (CLF), Random line (RND), Low responder (LR), High responder (HR). 0 means no correlation.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Species</th>
<th>Sample type (B/F)</th>
<th>Personality traits</th>
<th>Link to corticosterone?</th>
<th>Positive or negative correlation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baugh et al. (2017)</td>
<td>Great tits</td>
<td>Blood</td>
<td>Boldness</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Seltmann et al. (2014)</td>
<td>Eider</td>
<td>Blood</td>
<td>Boldness</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Eider</td>
<td>Blood</td>
<td>Boldness</td>
<td>Yes</td>
<td>Positive</td>
</tr>
<tr>
<td>Stöwe et al. (2010)</td>
<td>Great tits (Nestlings)</td>
<td>Faecal (dropping)</td>
<td>Exploration</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Baugh et al. (2012)</td>
<td>Great tits</td>
<td>Blood</td>
<td>Exploration</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Great tits (Wild)</td>
<td>Blood</td>
<td>Exploration</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Baugh et al. (2013)</td>
<td>Great tits</td>
<td>Blood</td>
<td>Exploration</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Martins et al. (2007)</td>
<td>Zebra finches</td>
<td>Blood</td>
<td>Exploration</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Kraj-Fišer et al. (2009)</td>
<td>Greylag goose (Semi-wild)</td>
<td>Faecal</td>
<td>Aggressiveness</td>
<td>Yes</td>
<td>Positive</td>
</tr>
<tr>
<td>Reference</td>
<td>Species</td>
<td>Sample type (B/F)</td>
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<td>----------------------------------</td>
</tr>
<tr>
<td>Grace &amp; Anderson (2014)</td>
<td>Nazca boobies (Wild)</td>
<td>Blood</td>
<td>Aggressiveness</td>
<td>Weak yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Sigoifo et al. (1996)</td>
<td>Rat (Wilde-type)</td>
<td>Blood</td>
<td>Aggressiveness</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Malkesman et al. (2006)</td>
<td>Rat (FSL), (SD), (WKY) and Wistar</td>
<td>Blood</td>
<td>Aggressiveness</td>
<td>Yes</td>
<td>Negative</td>
</tr>
<tr>
<td>Kralj-Fišer et al. (2009)</td>
<td>Greylag goose (Semi-wild)</td>
<td>Faecal</td>
<td>Sociability</td>
<td>No</td>
<td>0</td>
</tr>
</tbody>
</table>
3.1 Boldness and corticosterone

Réal and colleagues describe boldness as an individual’s reaction to a familiar situation that might present a risk. This can for example be an open feeding place that does not have any hiding places. Bolder individuals might be more prone to take the chance of being attacked by predators, if it means that they get access to more food. Shy individuals might look for a feeding place with less food but more hiding places.

In a study that was conducted on great tits, the results from behaviour testing and blood samples showed a negative correlation between boldness and corticosterone (Baugh et al. 2017, table 2), which means that bolder individuals had a lower level of corticosterone when being exposed to stress while shy individuals had an increased level of corticosterone.

This is opposite to a study done on eider (Somateria mollissima) females during breeding season. In this study boldness was measured by how close the researchers could get to the nest before the female eider flew away. Corticosterone levels were measured by blood samples after the eider had been handled by one of the researchers’ (Seltmann et al. 2014, table 2). The results showed that individuals that were referred to as bold individuals had a higher level of corticosterone than those individuals that were considered as shy. The different results might be explained by the way boldness is measured in the studies or by the different experience the individuals might have from before.

The importance of boldness and corticosterone has been shown in a study on eider females and nest site choices (Seltmann et al. 2014). Bold individuals with low levels of corticosterone seem to select nest sites further from the shore. This makes the risk for predators greater, but the benefits are for example, less exposure to cold wind from the water, more coverage of the nest and better survival chances for the chicks (Seltmann et al. 2014). It is still difficult to say if this depends only on the boldness-corticosterone correlation or if other factors, such as age, might change the nest site choice between breeding periods (Seltmann et al. 2014).

3.2 Exploration and corticosterone

Exploration describes how actively an individual searches through a new area or explore a new object. Individuals are often described as having either a fast or a slow exploratory behavior. Individuals that are fast explorers investigate the new surrounding or object quicker when introduced, while a slow explorer is more reluctant or slower to investigate (Verbeek et al. 1994). The trait ‘exploration’ could be an
important trait when find food, water and hiding places (Verbeek et al. 1994) and a fast explorer might be able to cover a larger area and thereby finding more resources than a slower explorer. However, a slow explorer might find all the resources in one area due to their close investigation of the surroundings.

Different bird species seem to show different directions in correlation between exploration trait and corticosterone. In a study with zebra finches (Taenopygia guttata), the individuals were selected for differences in their peak level of corticosterone levels after being exposed to a stressor and then tested on their exploratory behavior. The result showed that individuals selected for high peak levels of corticosterone showed an increase in exploratory behavior (Martins et al. 2007).

This result differs from results on great tits. Studies on great tits showed that birds that were selected for slow exploration had an increased corticosterone level after encountering a stressor (Stöwe et al. 2010, Baugh et al. 2012, Baugh et al. 2013). When using wild great tits, the result showed no correlation between exploration and corticosterone, at either corticosterone baseline or in corticosterone levels after encountering a stressor (Baugh et al. 2012). The lack of correlation might be explained by previous life experiences and the impacts these experiences might have had on the trait, the stress response or the correlation between them.

A second study that used wild great tits found that exploration had a negative correlation with corticosterone (Baugh et al. 2013). This is in line with the hypothesis that individuals with a more proactive coping style show lower levels of stress-induced corticosterone. The difference between these studies on wild great tits might be explained by differences in the individuals used in these two studies.

The difference between the studies on wild great tits and the one done on zebra finches is that the zebra finches were selected based on their peak levels of corticosterone while the great tits were selected for fast or slow exploration behavior. This might affect the correlation between exploration and corticosterone in a way we do not understand yet.

A study that compared great tit nestlings and adult great tits showed that nestlings and adults that had a slow exploratory personality also had a higher corticosterone baseline than fast exploratory individuals (Stöwe et al. 2010). When comparing nestlings with fast exploratory personality to individuals with slow exploratory personality, the result showed that nestlings that were considered slow explorers had higher stress-induced
corticosterone level than fast explorers. The next step might be to study a population from the early years to adulthood to see if and how different life experiences might affect the correlation between exploration and corticosterone.

There are strong indications that there may be a correlation between exploration and corticosterone levels in bird species due to the results in different studies, but the direction of this correlation is still not clear. It is unclear if this inconsistencies in the correlation only exist in birds or if it is true for other species as well. Studies done on rats regarding exploration and corticosterone are often combined with either depression or behavior disorders. This makes it difficult to tell if there is a correlation between corticosterone and exploration in healthy rats.

3.3 Activity and corticosterone

Activity is measured by the amount of movement an individual makes around in a familiar surrounding (Réale et al. 2007). This is the most difficult trait, described by Réale and colleges, in this literature study to tell if there is a correlation or not between the trait and corticosterone. The difficulty lies in the variety of measurements of activity that are used in different studies. Studies often focus on depression-like behavior when studying activity rather the studying just activity. So to get a clearer view regarding activity and its possible correlation to corticosterone the field of animal personality should agree on one method to measure activity.

3.4 Aggressiveness and corticosterone

By measuring how an individual reacts in a confrontation with conspecifics, the individual can be classified as either highly aggressive or less aggressive (Réale et al. 2007). Highly aggressive individuals are more likely to attack their conspecifics faster than low aggressive individuals (Koolhaas et al. 1999). Aggressiveness has been shown in vertebrates, fish and spiders, but when measuring aggressiveness researchers tend to frequently use rats and mice. Results from studies have shown that aggressiveness varies between different species of vertebrates but the correlation with corticosterone differed between studies and species.

This difference was shown when comparing two studies which both used wild individuals from different species of animals. One study was done on wild rats and did not show a correlation (Sgoifo et al. 1996) while one study on wild Nazca boobies showed a weak negative correlation (Grace & Anderson 2014). This difference is also present when comparing studies done on wild animals versus semi-wild animals. In a study done
on semi-wild greylag geese the correlation was positive (Kralj-Fišer et al. 2009). However, in the study on greylag geese, the researchers measured aggressiveness in terms of dimensions and there were other traits involved in the “aggressiveness” dimension. This makes it difficult to see if there are any correlations.

It is interesting that the correlation is so different between species that are considered to be prey and at the bottom of the food chain. You would think that less aggressive individuals, which are considered as prey, should show a higher level of corticosterone due to the impending risk of an attack from either conspecifics or predators regardless of species. It is difficult to determine what it is that might have caused these differences between studies. When using wild or semi-wild individuals it is difficult to keep track of all the factors and situations that happen in nature and how it affects the correlation between personality traits and corticosterone measured during the trails.

One study that used selected lines of rats showed a negative correlation between aggressiveness and corticosterone (Malkesman et al. 2006). However, these rats were selected for different levels of depression but showed a variation in aggressiveness compared to their controls and each other. The authors of the study discuss whether this can point towards two different depression types because of the difference in aggressive behavior. Flinders Sensitive Line (FSL) rats showed a more aggressive behavior than Wistar-Kyoto (WKY) rats. However, it is difficult to say anything about the natural correlation between aggressiveness and corticosterone from this study due to the fact that the rats used were selected on depression-like symptoms. It is unknown if these symptoms might affect the corticosterone levels connected to aggressiveness.

The results in a study using male Wistar rats showed that corticosterone affected the level of aggressiveness during social challenges but not during routine social life in established colonies (Mikics et al. 2007). They could see that only two of 54 rats became more aggressive towards cage mates after the injection of corticosterone (Mikics et al. 2007). This is interesting because this can mean that the expression of aggressiveness can differ between situations even if it is considered stable. This might mean that aggressiveness is a personality trait that is more fluctuating, depending on the situation and the level of stress the individual feels during a specific situation.

3.5 Sociability and corticosterone

Sociability is described as how an individual reacts to social situations. It can be measured by how an individual reacts to being far or close to its
conspecifics or how the individual reacts if removed from social group they are living in. Individuals that are more social will be close to its conspecifics and become more stressed if removed than less social individuals (Réale et al. 2007).

One study regarding sociability and corticosterone was made on semi-wild geese by Kralj-Fišer and collages (2009). The results from this study did not show a correlation between the personality trait and corticosterone. In this study the measurement of corticosterone was done by collecting feces samples after each test. This may not be accurate enough to see a weak possible correlation between sociability personality and corticosterone.

A study done on mandarin voles (Microtus mandarinus) showed a negative correlation between sociability and corticosterone (Qiao et al. 2014). In this study the corticosterone was extracted from blood instead of feces.

Both greylag goose and mandarin voles are highly social animals that live in close family groups (Madge & Burn 1988 cited by IUCN red list, Batsaikhan & Tsytsulina 2017). This makes the results interesting because you would think that a highly social individual should be more stressed and show higher levels of corticosterone when removed from its conspecifics than a low social individual. One reason can be that individuals that are seen as a high ranking individual within the group feel that they have more to lose if they are separated from the group (Kralj-Fišer et 2009). It may be that factors as self-confidence or the bonds within the group can affect the levels of corticosterone as well.

3.6 Societal & ethical considerations

To be able to provide the right protection and environment for the animal we care for, we need have a good understanding of the fundamental mechanisms that operate in the animals. If animal personality is correlated with stress hormones like corticosterone we will have to take this into consideration when we handle animals to reduce potential stress. The research on animal personality and its possible correlation to corticosterone can be used to improve animal welfare and production (Boissy et al. 2007). It is also important knowledge for politicians and law makers when they decide on new animal welfare and protection laws as well as for the people that are caring for animals in the animal production business.

If one wants to provide good welfare and housing with regards to, for example, exploration and its possible correlation with corticosterone, the focus should be on how to place enrichments in the housing environment
(Boissy & Erhard 2014). Individuals that have low exploratory behavior might become increasingly stressed if new enrichment is placed near the sleeping area or the feeding place. It might be wise to place it farther away so that the more exploratory individuals can investigate the new object without causing stress for the less exploratory individuals. This is important to have in mind because if an individual’s personality is not taken into consideration when trying to improve its welfare it can cause stress and depression-like behaviours (Boissy & Erhard 2014).

Further investigations regarding the possible correlation between personalities and corticosterone are important if we are to improve animal welfare and reduce the level of stress for the animals in our care.

3.7 Conclusion

The studies that have researched animal personality and a possible correlation with corticosterone show in most cases that there seems to be some type of correlation. However, no personality trait mentioned in this study showed a consistent correlation across studies or species. One reason to why there is no clear direction for the correlation, either in personality traits or across species, can be the variation in life experience between individuals. Another reason can be the variety of methods to measure animal personality within the personality traits or within species. The main conclusion I can draw from the literature study is that we still do not know what maintains the stability of animal personality within an individual.

4 Thanks

I would like to thank my tutor Hanne Løvlie for her support and guidance. I would also like to thank my examiner Jordi Altimiras for valuable input.
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