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Visual Discrimination, Seasonal & Sexual Dimorphism in Greylag Geese *(Anser anser)*: Deciphering Conspecifics Through Pictures

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Contents

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Introduction

Communication is a process that occurs across taxa and takes place, when information is conveyed from a sender to a receiver which then influences a receiver response (Gillam, 2011). This information can either be for example a cue, which is unintentional or a signal, which is intentional. Signals have the aim to purposely influence the behavior of the receiver in a way that benefits the sender (Irschick et al., 2015). One important aspect of signaling, is visual signaling, and is one of the most utilized types of signaling, due to it being easier to locate compared to other signal types. (Marler, 1967). Visual discrimination of those signals is a key aspect of visual signaling research. One study showed, for example, hyenas (*Crocuta crocuta)* display certain behavioral signals, only when in direct visual contact with the intended receiver (Nolfo et al., 2021). Another study on the American lobster (*Homarus americanus*) found, that when encountering a conspecific, American lobsters tended to avoid them or increase aggressive behavior only when the conspecific had previously been seen (Gherardi et al., 2010). While there is evidence for a visual domain for signaling, there is a gap in knowledge about visual discrimination behavior of individuals. For example, in avian species that live in large and socially complex groups, there could be selection on individual recognition, in particular so that tit-for-tat strategies and reciprocal altruism could confer benefits to individuals living in large stable groups (Trivers, 1971). Greylag geese (*Anser anser*) are an ideal model species for such research questions about individual-level recognition because they live in large flocks, some of which are stable across the year (Guggenberger et al., 2022).

Seasonal differences in animal signaling can be mediated by changes in hormone concentration, for example, and be associated with seasonal differences in reproductive behavior (Watts, 2020). Different bird species, for example male European nuthatches (*Sitta europaea*), have been shown to be more aggressive in the breeding season, due to their elevated testosterone levels during this period (Landys et al., 2010). Northern Bald Ibises

(*Geronticus* eremita) have also shown to display more affiliative behaviors during the breeding season, perhaps to reinforce their pair-bond stability (Puehringer-Sturmayr et al., 2020). This pair-bond reinforcement has also been studied in Canada geese (*Branta canadensis*), who have been shown to engage in certain affiliative behaviors like calling and triumph ceremonies, to strengthen their pair-bonds (Akesson & Raveling, 1982).

Furthermore, Individuals may target other individuals for the exchange of behavior in relation to the value of the relationship (Silk, 2007). Affiliative and agonistic behaviors between other group members in relation to the social value of the partner have been shown in different animal groups. In some primate societies, for example, affiliative behavior occurs frequently between certain social dyads resulting in the concept of social allies (Mitani et al., 2012). In birds such as Siberian jays (*Perisoreus infaustus*), when individuals are less genetically related to one another, there is a noticeable increase in agonistic behavior (Griesser et al., 2015). In greylag geese, some juveniles remain in close proximity to their parents again after having fledged (Szipl et al., 2019), and support their parents in agonistic displays towards other flock members. Therefore, differentiating between relatives and non-relatives may be selected for and be associated with patterns of affiliative and agonistic behavior.

Greylag geese (*Anser anser*) are a good model system to study individual-level recognition and the direction of affiliative and agonistic behavior (Kleindorfer, 2024). For example, they have signature distance calls that are recognized by partners versus non-partners (Guggenberger et al., 2022). When it comes to visual recognition, there are different indicators that could lead to this process. For example, these could be phenotypical differences in height, feather colors or facial structures. This was tested during 2019 and 2023 with a software program that found 98% accuracy in facial recognition using photos (Kleindorfer et al. 2024. Researchers used life-size photos and also confirmed that the greylag geese respond to different categories of photos in response to photographs of themselves, their partners or other flock mates. The findings of Kleindorfer et al. (2024) provided evidence that, during the non-breeding season, the geese showed more affiliative behavior towards photos of their partners than non-partners. There were no sex differences during the non-breeding season in response to the photos. Sex differences in birds´ agonistic behavior is expected however (Kikkawa et al., 1986; Weiss et al., 2011), especially during the breeding season, which is also found for greylag geese during the breeding season (Kotrschal et al., 1993).

My research thesis asks if greylag geese show a differentiated response to photos of other geese and also asks, if geese show a difference in behavior when comparing the breeding season with the non-breeding season. I also ask if there is a difference in behavior when comparing the responses in females and males, not least because testosterone levels in males would be much higher during the breeding season as opposed to the non-breeding season (Hirschenhauser et al., 2000), and would also be much higher in males than females. I test four hypotheses. The **first hypothesis** is that greylag geese perceive the visual stimulus of wooden boards and photos differently and therefore respond to these stimuli in a different manner. I predict a difference in affiliative and agonistic behavior by geese exposed to a goose photo (treatment) or a wooden board (control). The **second hypothesis** is that greylag geese visually discriminate between different social categories tested using life-size photos. I predict the geese will show the most affiliative behavior towards a photo of their partner, some affiliative behavior towards a photo of a relative, and the least amount of affiliative behavior towards a photo of a familiar but unrelated flock member (partner > relative > flock mate). Regarding the agonistic behavior, I expect the geese to be the most agonistic when presented with a picture of a partner and the least when presented with a picture of a flock mate (partner > relative > flock member). The **third hypothesis** is, that during the breeding season, affiliation and agonism increases compared to the non-breeding season. I expect higher values of affiliative and agonistic behaviors in the breeding season dataset (2023) compared to the non-breeding season dataset (2021). The **fourth hypothesis** is, that there are pronounced sex differences in agonistic behavior during the breeding season as males defend fertile and egg-laying females. I expect males to have higher scores for all agonistic variables in the breeding season dataset (2023).

Materials & Methods

Study species and study site

The subjects of this study were a greylag goose flock of 119 individuals that live near the Konrad Lorenz Research Center (Konrad Lorenz Forschungsstelle, KLF) in the Alm valley, Grünau im Almtal, Austria. The goose flock was introduced in 1973 by the scientist Konrad Lorenz. The flock is free-ranging and non-migratory, with food supplementation provided twice a day at the Auingerhof, the original KLF building (47°48’49.4” N 13°56’51.9” E). Over the past decades, many studies have been conducted on these geese (Scheiber et al., 2013) (Kleindorfer, 2024) (Lorenz, 1988). The life history and behaviour of the geese, as well as their relationships with other conspecifics, has been systematically monitored, which provided to this day a lot of information regarding their age, sex, relationship to others and social dynamics (flock members, relatives, partners, etc.) Due to the consistent interactions between the geese and the humans (research and feeding) the geese have habituated to their presence. In addition to being habituated, 98% of the flock have individual markings using colored rings around their legs (Frigerio, 2023) and thus allows for identification of the individuals when conducting research.

Experimental design

For my thesis I collected data during the greylag goose breeding season, which took place from April to May 2023, and compared this to the data collected during the non-breeding season in October and November 2022 (Kleindorfer et al. 2024). The experimental design involved placing five wooden boards at five different locations separated by 50-100 m at the Auingerhof. I then placed four rocks (see Fig. 1) around each of the wooden boards to mark two radii at a distance of one meter and two meters, respectively, forming two semi-circles (see Fig. 2). These semi-circles have two cut-outs at an angle of roughly 10°. This is so, because if the geese approach the experimental trial area from behind, they would only be able to perceive the front side of the boards from a certain angle. I placed GoPro cameras outside of the two-meter radius and captured video footage of all interactions among the geese, both with the boards and with one another. The data collection took place twice a day, once in the morning and once in the afternoon. These sessions consisted of a two-hour recording period and started one week after the introduction of the wooden boards to the area, so that the geese could get habituated to their presence. Prior to this study, life-sized photographs (A0 Format) were taken of 50 members of the flock. These non-reflective and waterproof photographs were used to test the response of geese to photographs of other geese.

Figure 1: Set up of the photo trials at the Auingerhof (original KLF building)

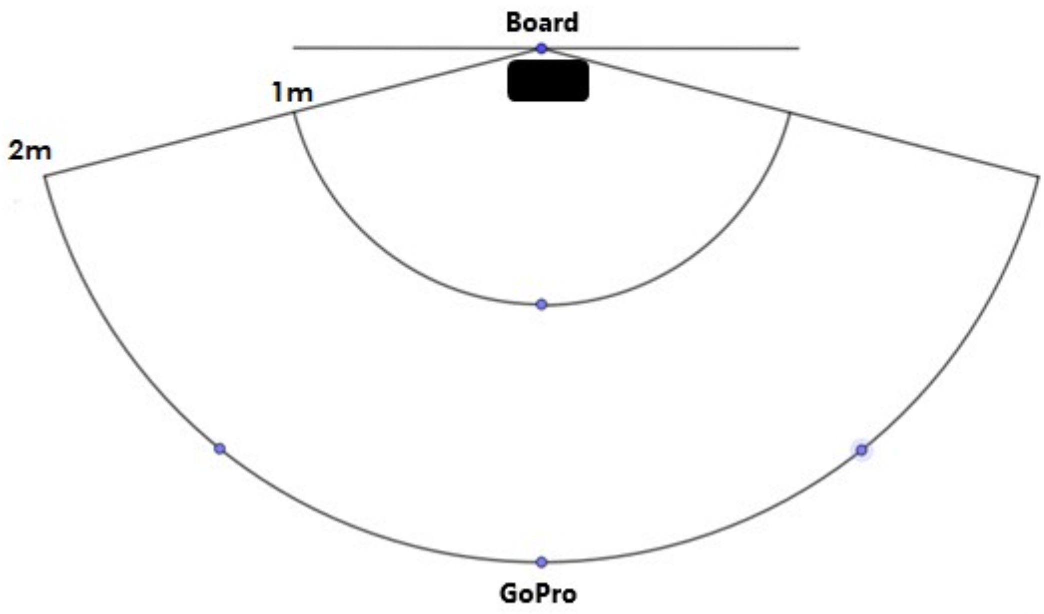

Figure 2: Top-down representation of the trial set up

Experimental protocol

In this study I utilized 46 of the previously mentioned photographs in order to present the approaching geese with three different treatments (photo trials) (four photographs of the original 50 were not used because the geese had died due to predation). I first noted all geese present at the feeding meadow on the day of the trial and selected photographs to test for response to partner versus relative versus flock member by placing photographs of the intended dyads on the boards. I also conducted control trials, which consisted of using the wooden boards alone, without the photographs. For each trial type (partner, relative, flock member and control), I only analyzed each goose's first encounter, to avoid the confounding factor of habituation. I collected a total of 97 first interactions consisting of 32 controls and 64 photo trials (35 flock member trials, 13 partner trials and 16 relative trials) (29 female trials and 67 male trials total).

Affiliative and agonistic behavior

This study focuses on two main behaviors: affiliation and agonism. I selected the following variables to measure affiliative behavior: (1) Latency to approach a 1-meter radius, (2) Feeding duration within a 1-meter radius, (3) Minimum distance, and (4) Total number of contact call bouts. These variables are a good measure of affiliation, since previous studies have shown that proximity and contact calls play an important role in prosocial interactions (Scheiber & Weiß, 2018) (Guggenberger et al., 2022).

For agonistic behavior, the variables I measured are the following: (1) Vigilance events (long-neck up), (2) forward long-neck displays, (3) hissing, and (4) pecking/attacking/chasing. The variables have also shown in previous literature to be good representatives of agonistic behavior in greylag geese (Kotrschal et al., 1992) (Scheiber et al., 2013) (Young, 1972).

Statistical analysis

I analyzed the obtained data utilizing the programming software R.

As a primary step, during each recording, I began the trial period of photo and focal goose interaction after an individual entered the 2-meter radius. This was counted as the initiation of the trial, which had a length of five minutes. In order for the trial to be added to the dataset, there were two prerequisites that had to be fulfilled: 1. The individual had to have encountered that trial type for the first time (control, flock member, relative, partner) 2. Within the five minutes, the individual needed to be inside the 2-meter radius for at least three minutes. If these conditions were met, then I coded into the coding software “Solomon Coder” all previously mentioned behaviors that were performed within the five minutes of each trial. After completing the dataset (2023), I combined it with the dataset collected during the non-breeding season of 2021 (Heger, 2021) and proceeded with the statistical analysis by employing R.

Firstly, I compared the geese’s behavior with the presence of the photographs to their behavior with only the wooden boards (controls). This gave information about whether the board itself influences affiliative or agonistic behavior. Subsequent to that, I performed a similar comparison between the three trial types (partner, relative, flock member). Succeeding that, I compared the dataset of the breeding season (2023) with the dataset of the non-breeding season (2021), including a comparison between the two sexes, also regarding the same variables from the combined datasets. All variables were analyzed separately.

The test I applied in order to analyze the collected data, was a Linear Mixed-Effects Model with restricted maximum likelihood (REML) estimation, and the trial types as well as the sex as the fixed factors and the goose IDs as the random factor. I utilized t-tests with degrees of freedom approximated by Satterthwaite´s method to assess the significance of the fixed effects.

Results

Breeding Season (see Tabs. 1 and 2)

Photo & Control Trials Regarding Affiliative Behavior: Breeding Season

The variables “latency to approach a 1-meter radius” ($P < 0.001$) and the “feeding duration within a 1-meter radius” ($P < 0.003$) showed a significant difference between photo and control trials (see Fig. 3). The control trials had significantly lower scores for the latency to approach 1-meter and longer feeding duration within a 1-meter radius. The variables “contact Call Bouts” ($P = 0.187$) and “minimum distance” ($P = 0.201$) did not show a statistically significant difference when comparing the photo trials to the control trials.

Photo & Control Trials Regarding Agonistic Behavior: Breeding Season

In the comparison between photo and control trials regarding agonistic behavior, the behavior involving hissing towards the photograph, showed overall higher values for the photo trials (see Fig. 4), whereas the other variables showed no statistically significant differences between the photo and control trials. [Hissing (photo) ($P = 0.002$), vigilance events ($P = 0.327$), forward long neck displays (photo) ($P = 0.108$), forward long neck displays (other) ($P = 0.196$), hissing (other) ($P = 0.103$), pecks/attacks/chases (photo) ($P = \varnothing$), pecks/attacks/chases (other) ($P = 0.214$)].

Photo Trials Regarding Affiliative Behavior: Breeding Season

When comparing the three types of relationships within the photo trials (flock member, relative, partner), the variable “feeding duration within a 1-meter radius” showed a statistically significant difference between the relationship category “partner” and both the categories “flock member” and “relative” [Partner – Flock member ($P = 0.033$); Partner – Relative ($P = 0.049$)] but no difference between the categories “flock member” and “relative” ($P = 0.905$). Furthermore, within the variable “minimum distance”, the categories “partner” and “flock member" showed a statistically significant difference (P = 0.007), whereas the comparisons between the categories "flock member" and "relative" (P = 0.427) as well as "partner" and "relative" (P = 0.08) showed no significant difference (see Fig. 5). On the other hand, the results of the affiliative variables "latency to approach 1-meter" and "contact call bouts" showed no significant differences between any relationship category [latency to approach 1-meter (Flock member – Partner (P = 0.804); Flock member – Relative (P = 0.959); Partner – Relative (P = 0.793)), contact call bouts (Flock member – Partner (P = 0.278); Flock member – Relative (P = 0.905); Partner – Relative (P = 0.299))].

Photo Trials Regarding Agonistic Behavior: Breeding Season

Within the photo trials, none of the agonistic variables were significantly different across relationship categories [Vigilance events (Flock member – Partner (P = 0.849), Flock member – Relative (P = 0.399), Partner – Relative (P = 0.465)); forward long neck displays (photo) (Flock member – Partner (P = 0.93), Flock member – Relative (P = 0.489), Partner – Relative (P = 0.525); forward long neck displays (other) (Flock member – Partner (P = 0.847), Flock member – Relative (P = 0.067), Partner – Relative (P = 0.185)); hissing (photo) (Flock member – Partner (P = 0.572), Flock member – Relative (P = 0.692), Partner – Relative (P = 0.992)); hissing (other) (Flock member – Partner (P = 0.201), Flock member – Relative (P = 0.594), Partner – Relative (P = 0.59)); pecks/attacks/chases (photo) (Flock member – Partner (P = ∅), Flock member – Relative (P = 1), Partner – Relative (P = 1)); pecks/attacks/chases (other) (Flock member – Partner (P = 0.419), Flock member – Relative (P = 0.789), Partner – Relative (P = 0.354))].

Combination Of Breeding Season Dataset (2023) & Non-breeding Season Dataset (2021) (see Tabs. 3 and 4)

Photo & Control Trials Regarding Affiliative Behavior: Breeding Season & Non-breeding Season

In the comparison between the photo and control trials of both the breeding season (2023) and the non-breeding season (2021) dataset combined, three of the four analyzed behaviors indicate a statistically significant difference between control and treatment (see Fig. 6). The control trials showed a shorter latency to approach a 1-meter radius ($P = 0.004$), a longer feeding duration within 1-meter ($P = 0.007$) as well as a shorter minimum distance ($P < 0.001$). The variable "contact call bouts" was not significantly different.

Photo & Control Trials Regarding Agonistic Behavior: Breeding Season & Non-breeding Season

Regarding the agonistic behaviors, the variables "forward long neck display (total)" ($P = 0.011$) as well as "hissing (total)" ($P = 0.006$) also indicated a significant difference between control and treatment, with the values being overall higher in the photo trials (see Fig. 7). On the other hand, the variables "vigilance" ($P = 0.396$) and "pecks/attacks/chases (total)" ($P = 0.975$) did not showcase a significant difference between the trial types.

Photo Trials Regarding Affiliative Behavior: Breeding Season & Non-breeding Season

In the case of the photo trials, during the non-breeding seasons, all four affiliative behaviors were significantly different between the variable "partner" and both the variables "flock member" and "relative" (see Fig. 8). The relationship type "partner" had a shorter latency to approach a 1-meter radius [Partner – Flock member ($P = 0.005$); Partner – Relative ($P < 0.001$)], a longer feeding duration within 1-meter [Partner – Flock member ($P = 0.011$); Partner – Relative ($P = 0.007$)], a higher amount of contact call bouts [Partner – Flock member (P =

0.012); Partner – Relative (P = 0.014)] as well as a shorter minimum distance [Partner – Flock member (P < 0.001); Partner – Relative (P < 0.001)] during the breeding than non-breeding season. The results did not show a difference between the relationship types "flock member" and "relative" [Latency to 1-meter (P = 0.261); Feeding within 1-meter (P = 0.639); Contact call bouts (P = 0.841); Minimum distance (P = 0.709)].

Photo Trials Regarding Agonistic Behavior: Breeding Season & Non-breeding Season

Regarding the agonistic behaviors during the non-breeding season, none of the variables were significantly different between the relationship types [Vigilance (Flock member – Partner (P = 0.438), Flock member – Relative (P = 0.46), Partner – Relative (P = 0.188); Forward long neck display (total) (Flock member – Partner (P = 0.664), Flock member – Relative (P = 0.25), Partner – Relative (P = 0.643); Hissing (total) (Flock member – Partner (P = 0.535), Flock member – Relative (P = 0.245), Partner – Relative (P = 0.755); Pecks/attacks/chases (total) (Flock member – Partner (P = 0.336), Flock member – Relative (P = 0.451), Partner – Relative (P = 0.146)].

Comparison Between Breeding Season (2023) And Non-breeding Season (2021) (see Tabs. 5, 6, 7 and 8)

General Comparison Of Affiliative And Agonistic Behavior

Overall, the dataset from the breeding season showed, compared to the non-breeding season dataset, significantly higher values in the affiliative behaviors “latency to approach 1-meter” ($P < 0.001$), “feeding duration within a 1-meter radius” ($P < 0.001$) and “contact call bouts” ($P = 0.002$) (see Fig. 9). The behavior “minimum distance” ($P = 0.902$) did not show a significant difference between the two datasets.

Furthermore, all four agonistic behaviors also showed a significant difference between the two seasons (see Fig. 10). Greylag geese during the breeding season had more agonistic behavior than during the non-breeding season [“vigilance” ($P < 0.001$), “forward long neck display (total) ($P < 0.001$), “hissing (total)” ($P < 0.001$), “pecks/attacks/chases (total)” ($P < 0.001$)].

Similar results were acquired when comparing only the control trials across both seasons, with the exception of the behavior “contact call bouts” ($P = 0.562$), which did not show a significant difference between both seasons (see Figs. 11 and 12). [“Latency to approach 1-meter” ($P < 0.001$), “feeding duration within a 1-meter radius ($P < 0.001$), “minimum distance” ($P = 0.477$)], “vigilance” ($P < 0.001$), “forward long neck display (total) ($P < 0.003$), “hissing (total)” ($P < 0.001$), “pecks/attacks/chases (total)” ($P < 0.001$)].

Agonistic Behavior Regarding Sex (Photo + Control Trials) (see Tab. 9)

Breeding Season (2023)

In relation to both the photo and control trials of the breeding season dataset (2023), the agonistic response variables "vigilance" ($P < 0.001$), "hissing" ($P = 0.022$) and "pecks/attacks/chases" ($P = 0.033$) were significantly different between the sexes (see Fig. 13). Males displayed higher agonistic scores than females on these variables. The variable "forward long neck display" ($P = 0.074$) does not show a significant difference.

Non-breeding Season (2021)

In the context of the non-breeding season dataset (2021), none of the agonistic response variables were significantly different between the sexes (see Fig. 14). [Vigilance events ($P = 0.177$), forward long neck displays ($P = 0.099$), Hissing ($P = \varnothing$), pecks/attacks/chases ($P = \varnothing$)].

Discussion

My thesis reports on behavioral differences in greylag geese, towards life-size photos of conspecifics, that differ across social classes of the dyad relationships to the photos and across seasons. When comparing photo trials to control trials regarding affiliative behavior of the combined datasets (breeding season 2023 and non-breeding season 2021), the results indicate, that geese took significantly longer to approach the 1-meter radius when presented with a picture of another goose, as opposed to a control wooden board. Additionally, within the 1-meter radius (including the feeder) the geese also fed for almost half the amount of time, when presented with a picture of a goose over a wooden board. Moreover, the results also show, that the geese spent their trial time in closer proximity to the wooden boards compared to the photos. Given these results, it can be said, that the presence of life-sized photos of geese influences the behavior of greylag geese.

Furthermore, when looking at the agonistic behaviors of the combined datasets, the results show, that the geese performed more forward long neck displays when presented with a photo of a goose as opposed to the wooden board alone. The geese also engaged more in the behavior of hissing when a photo of a goose was presented. These findings allude to the idea, that the geese perceive the photos as actual geese, and therefore change their agonistic behavior compared to when no photo is presented. This goes in line with the concept, that visual cues are at least one of the driving factors that influence the behavior of greylag geese.

The two agonistic behaviors of vigilance and the combination of pecks, attacks and chases, as well as the affiliative behavior of contact call bouts, did not show a statistically significant difference between the two trial types. A possible explanation for this could be, that when the geese start a trial, regardless of whether a photo is presented or not, there are still other geese present in the area during the trial. Perhaps the geese’s affiliative and agonistic behavior could still be influenced by other geese that are near the subject being tested. Therefore, it might be interesting to focus only on the behaviors directed at the boards and photos.

For example, when focusing on the behavior of hissing in the breeding season dataset (2023), the obtained data appears to show a difference in behavior, regarding hissing at the photo and hissing at others. When it comes to hissing at others, the results did not show a significant difference between hissing when a photo is present and hissing when a photo is absent. This could be because the geese were often surrounded by other geese in the area within 50 and 100 m and could therefore have been defensive regardless of the situation at the wooden board. When it comes to hissing at the photo however, the results indicate, that on average, the geese only hiss at the photo if a photo is present. Although, the results indicated a relatively small difference between the average amounts of hisses at the photo, it is still worth mentioning, due to the fact that its significance shows, there is a difference between the perception of the wooden board when it is attached to a photo of a goose and when it is not.

In light of the presented findings, it can be said to a certain degree, that these results support my first stated hypothesis.

Moreover, within the photo trials of the combined datasets (breeding season 2023 and non-breeding season 2021), in relation to the affiliative behaviors, all four behaviors showed the same statistically significant differences between the three trial types. The findings show that when it came to a photo of a partner, compared to the trials with photos of relatives or other flock members, the subjects of the trials took less time to approach the photo, spent more time feeding near the photo, performed more contact call bouts and had a smaller minimum distance to the photo. This result correlates with the expectation, that geese are the most affiliative with photos of their partners and is something, that can be tested well throughout the whole year, given the fact, that geese are one of the species that form partnerships that can last several years or even persist the entirety of their life (Scheiber et al., 2013). In addition, it is also interesting to note, that while observing the affiliative behaviors, the geese’s behavior towards flock members and relatives is rather similar and does not show a significant difference between the two relationships. Several studies have shown, that more so, partners and relatives play similarly important roles in active and passive social support, helping in agonistic situations and over all lowering cortisol levels with their presence (Scheiber et al., 2009) (Weiß & Kotrschal, 2004) (Scheiber et al., 2005). Nevertheless, studies have also shown, that social bonds amongst relatives can vary. For example, female greylag geese have shown to be rather closer to sisters than brothers (Frigerio et al., 2001). A further study has also shown, female parents stay in closer proximity to their young offspring than males (Szipl et al., 2019), which raises the question if sub-adult or adult geese are also more closely bonded to their mother than to their father. Hence, it might be interesting to conduct further research on how differently relatives are treated in greylag geese flocks when taking into consideration the different levels of kinship such as half-siblings, cousins, grandparents, etc.

On the other hand, within the photo trials of the combined datasets (breeding season 2023 and non-breeding season 2021), in relation to the agonistic behaviors, none of the results showed a significant difference between either of the three trial types. This also suggests the idea, that the geese's agonistic behavior, could be influenced by the presence of another goose during the trial. When looking at the results of the breeding season dataset (2023) (see Tab. 2), it appears to be, as if the geese direct most of their agonistic behaviors towards other geese rather than the photo. Therefore, it makes sense to expect the geese to be more agonistic when presented with a photo of the partner, since the agonistic behaviors would, in that case, most likely be directed towards other geese in order to defend their partner (photo). However, there were, for example, instances, in which the geese entered the trial (partner, relative or flock member) while being accompanied by their actual partner. Hence, it becomes somewhat complicated to define, whether the geese are being influenced more by the photo or by the geese near them, given the fact, that they are being visually stimulated by both. Thus, as mentioned, it might be compelling to conduct further research, with a separation between the agonistic behaviors directed towards the photo and the agonistic behaviors directed towards other geese.

Given the presented findings, it can be said, that the results partly support my second hypothesis and go somewhat in line with the expectations regarding the geese's affiliative behavior.

Alongside the mentioned findings, when comparing the results from the breeding season dataset (2023) with the results from the non-breeding season dataset (2021) regarding affiliative behavior, the geese showed to be more affiliative during the breeding season (2023), in three of the four analyzed behaviors. In addition to that, the results also showed, that the geese were more agonistic during the breeding season (2023) than during the non-breeding season (2021). This comparison showed almost the same results when only analyzing the control trials, which implies, that the baseline level of response to the control differs across seasons. This goes in line with my expectations, since there are affiliative behaviors such as triumph ceremonies and calling, that can be tied to agonistic behaviors. The presented findings support the idea that geese (regardless of sex) become more affiliative and agonistic during the breeding season, probably due to aims of reenforcing pair-bonds and other prosocial relationships as well as the affinity to establish territorial boundaries protecting one's own eggs and goslings and also the egg-laying females.

It can therefore be said, the presented results support my third hypothesis.

Lastly, when looking at the geese's agonistic behavior during the breeding season regarding sex, three of the four behaviors showed that males were significantly more agonistic than females. This result coincides with my expectations, since during the breeding season, male snow geese (*Anser caerulescens*) have been shown to spend more time than females engaging in agonistic behaviors (Gauthier, 1991) (Akesson & Raveling, 1982). This could be due to an elevation of testosterone levels during this period as well as a difference in behaviors, which have different roles to support the offsprings, for example, feeding in females to increase the egg sizes and weights and aggressive behaviors in males to protect the family. In addition to this it is worth mentioning, that, in the non-breeding season dataset, no agonistic behavior showed this difference between females and males. A study on barnacle geese

(*Branta leucopsis*), for example, has also shown a sexual difference in agonistic behavior during the breeding season as well as a change in which females started performing almost just as many agonistic behaviors as males when entering the non-breeding season (Akesson & Raveling, 1982). A possible explanation for this is, that after the breeding period, when the goslings fledge, testosterone levels decrease, and other variables than sex might influence agonistic behavior just as much, for example weight, age, social status, etc.

Considering the presented information, it can be stated, this study supports my fourth hypothesis.

All in all, it can be concluded, that this study provides valuable information, about greylag geese, since according to the results, they seem to perceive photos of other greylag geese as categories of conspecifics and therefore the study sheds light on the importance of visual cues in greylag geese, and thus advocates for the use of these life-sized photos in future research that intends to simulate the presence of geese. Moreover, this study also provided information about the seasonal affiliative and agonistic behavior of greylag geese, and thus supports the fact that the months of April and May are adequate months for conducting research on affiliation and agonism in greylag geese, since these behaviors might be more abundant during this period. This thesis renders significant data about the geese's reactions towards photos of partners, relatives and flock members, and the presented pattern emphasizes the importance of pair-bonds and also indicates, that further research about the relationships between certain relatives in comparison to other flock members, could be of relevance. These presented results regarding photos of partners alludes to a possibility of utilizing these photos on geese that have to be separated from the flock for medical care, and possibly render a sort of therapeutic effect by simulating the presence of partners. Regarding the seasonal behavior, the results show overall higher agonism and affiliation during the breeding season (2023). It would be interesting to conduct further research on which groups exactly are more affiliative, since for example juvenile greylag geese have shown to be more social during the winter (Szipl, Depenau, et al., 2019). One should keep in mind that there are still many factors that can influence affiliative behaviors throughout the seasons like the establishing of pair-bonds outside of the breeding season but also the reinforcement of those bonds during the breeding season.

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Tables & Figures

Table 1: Breeding season dataset (2023), Means & Standard Errors (Affiliative)

Mean & SE	Latency to 1m	Feeding 1m	Call Bouts	Minimum Dist.
Controls	52.1 ± 17.1	126.9 ± 18	0.6 ± 0.2	1 ± 0.1
Photos	141.3 ± 16.2	68.4 ± 10.4	1.2 ± 0.3	1.1 ± 0.1
Flock Member	148.8 ± 22.9	54.2 ± 13	1 ± 0.3	1.3 ± 0.1
Partner	130.6 ± 35.6	109.4 ± 27.5	1.9 ± 1.3	0.7 ± 0.2
Relative	133.3 ± 31.2	65.9 ± 19.6	0.9 ± 0.4	1.1 ± 0.2

Table 2: Breeding season dataset (2023), Means & Standard Errors (Agonistic)

Mean & SE	Vigilance	Long Neck Photo	Long Neck Others	Hissing Photo	Hissing Others	Pecks/Attacks /Chases Photo	Pecks/Attacks /Chases Othres
Controls	4.3 ± 1	0 ± 0	0.9 ± 0.4	0.2 ± 0.2	0.7 ± 0.3	0 ± 0	0.8 ± 0.3
Photos	3.4 ± 0.7	0.3 ± 0.1	1.4 ± 0.3	1.2 ± 0.3	0.9 ± 0.2	0 ± 0	0.5 ± 0.1
Flock Member	2.9 ± 0.9	0.3 ± 0.1	1 ± 0.4	1.6 ± 0.6	1.1 ± 0.4	0 ± 0	0.5 ± 0.2
Partner	5 ± 2.2	0.3 ± 0.3	1.2 ± 0.5	0.9 ± 0.5	0.5 ± 0.2	0 ± 0	0.7 ± 0.3
Relative	3.3 ± 0.9	0.1 ± 0.1	2.4 ± 0.7	0.7 ± 0.4	0.9 ± 0.4	0 ± 0	0.4 ± 0.2

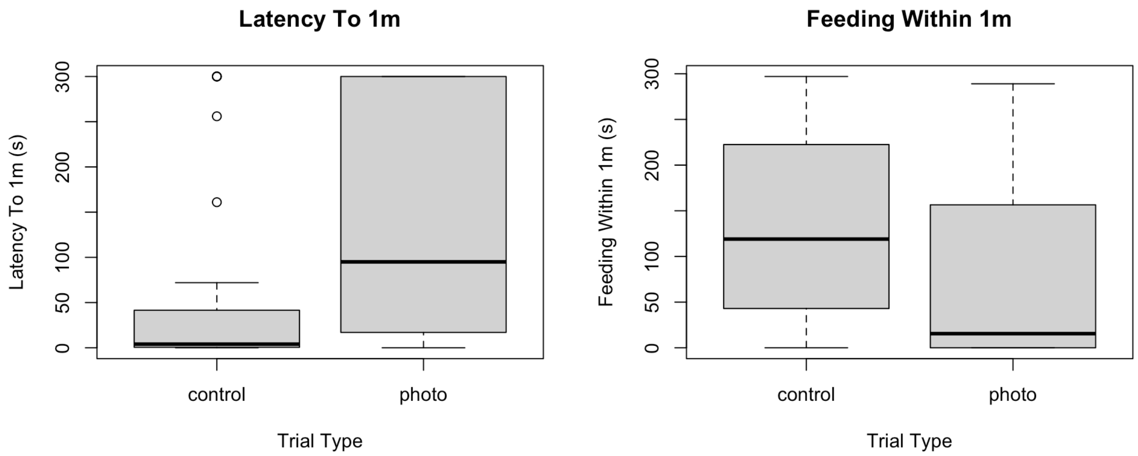

Figure 3: Breeding season dataset (2023), Boxplots of photo & control trials (affiliative behavior)

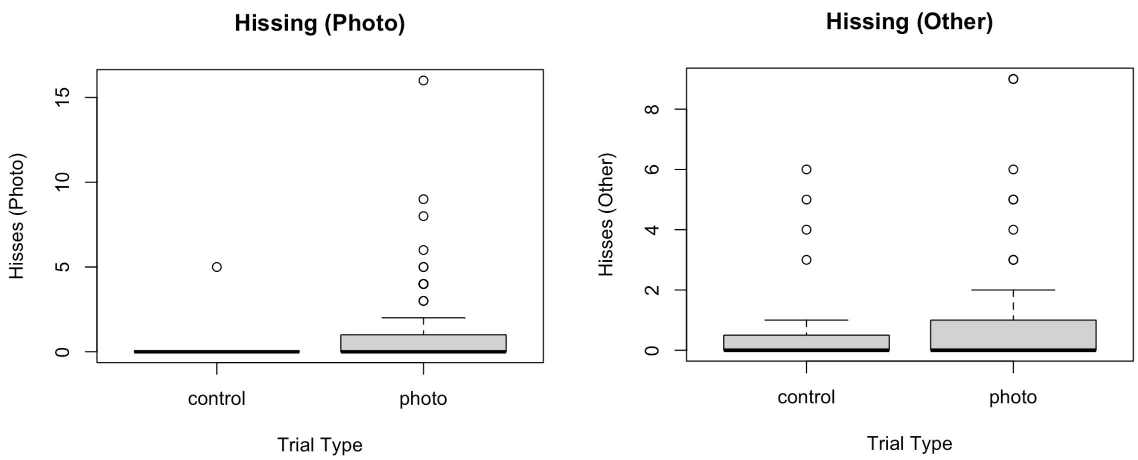

Figure 4: Breeding season dataset (2023), Boxplots of photo & control trials (agonistic behavior)

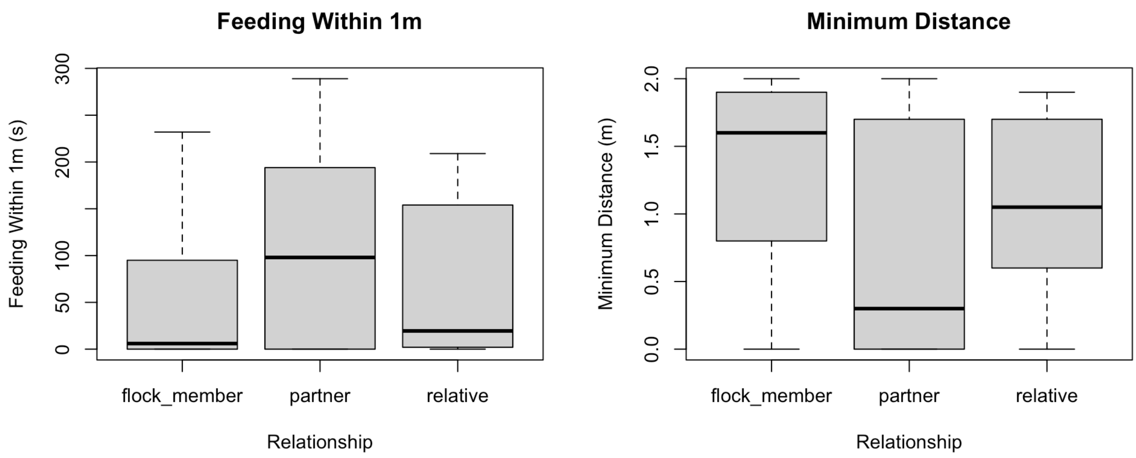

Figure 5: Breeding season dataset (2023), Boxplots of photo trials (affiliative behavior)

Table 3: Breeding Season (2023) and Non-breeding Season Data (2021) Combined, Means & Standard Errors (Affiliative)

Mean & SE	Latency to 1m	Feeding 1m	Call Bouts	Minimum Dist.
Controls	148.2 ± 12.6	57.8 ± 7.9	0.4 ± 0.1	0.9 ± 0.1
Photos	195.2 ± 10.5	34.4 ± 5.5	0.6 ± 0.2	1.2 ± 0.1
Flock Member	201 ± 14.8	29.3 ± 6.8	0.5 ± 0.1	1.3 ± 0.1
Partner	119.6 ± 21.7	66.6 ± 18	1.5 ± 0.7	0.6 ± 0.1
Relative	227.1 ± 17,6	25.3 ± 8.6	0.4 ± 0.2	1.4 ± 0.1

Table 4: Breeding Season (2023) and Non-breeding Season Data (2021) Combined, Means & Standard Errors (Agonistic)

Mean & SE	Vigilance	Long Neck Total	Hissing Total	Pecks/Attacks /Chases Total
Controls	1.2 ± 0.3	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.1
Photos	1.6 ± 0.3	0.8 ± 0.2	1 ± 0.3	0.2 ± 0.1
Flock Member	0.4 ± 0.5	0.6 ± 0.2	1.3 ± 0.4	0.2 ± 0.1
Partner	2.9 ± 1.3	0.8 ± 0.3	0.8 ± 0.4	0.4 ± 0.2
Relative	1.3 ± 0.4	1 ± 0.3	0.6 ± 0.3	0.1 ± 0.1

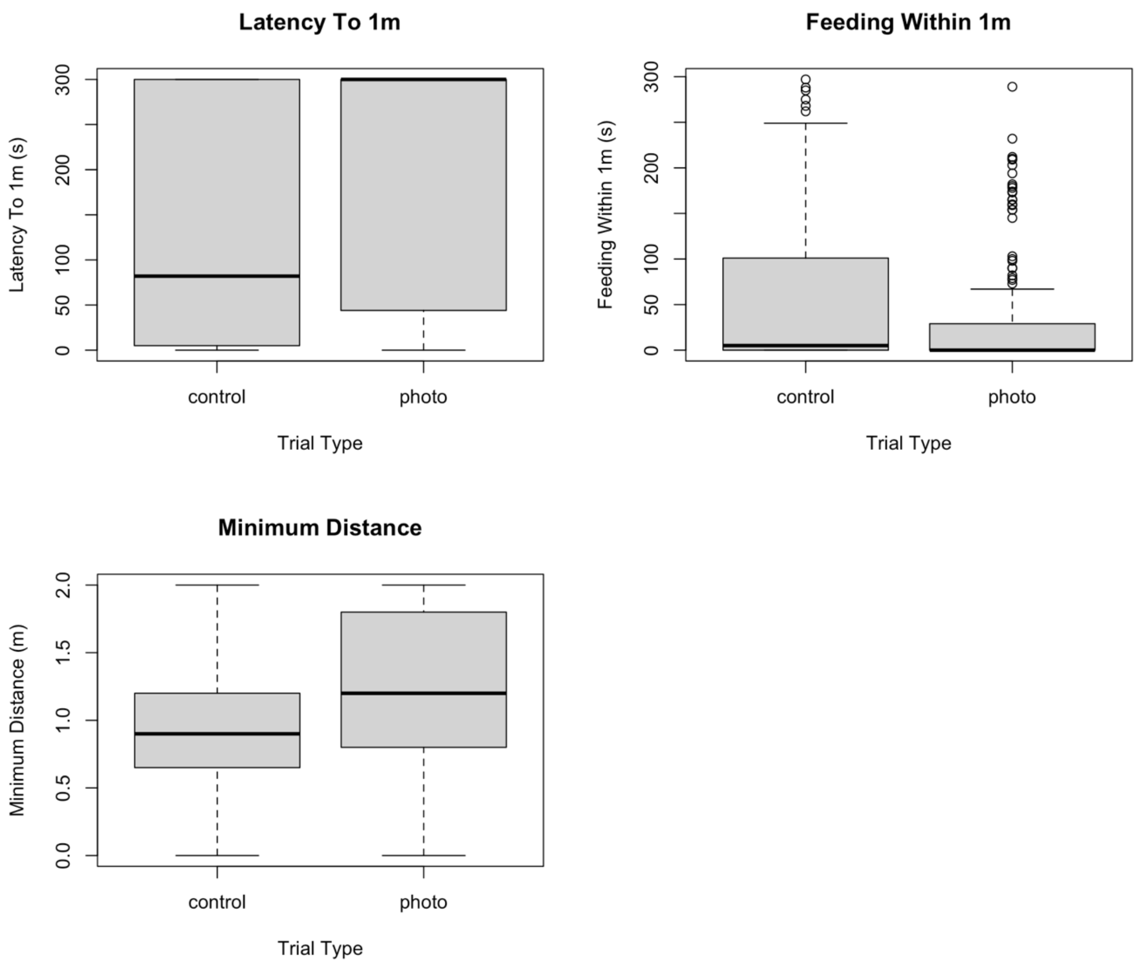

Figure 6: Breeding Season (2023) & Non-breeding Season Data (2021) Combined, Boxplots of photo & control trials (affiliative behavior)

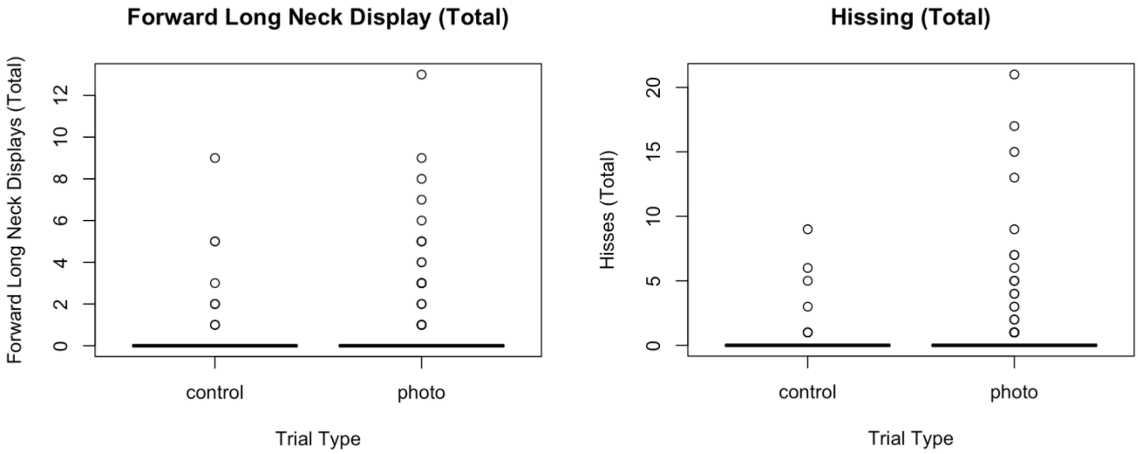

Figure 7: Breeding Season (2023) & Non-breeding Season Data (2021) Combined, Boxplots of photo & control trials (agonistic behavior)

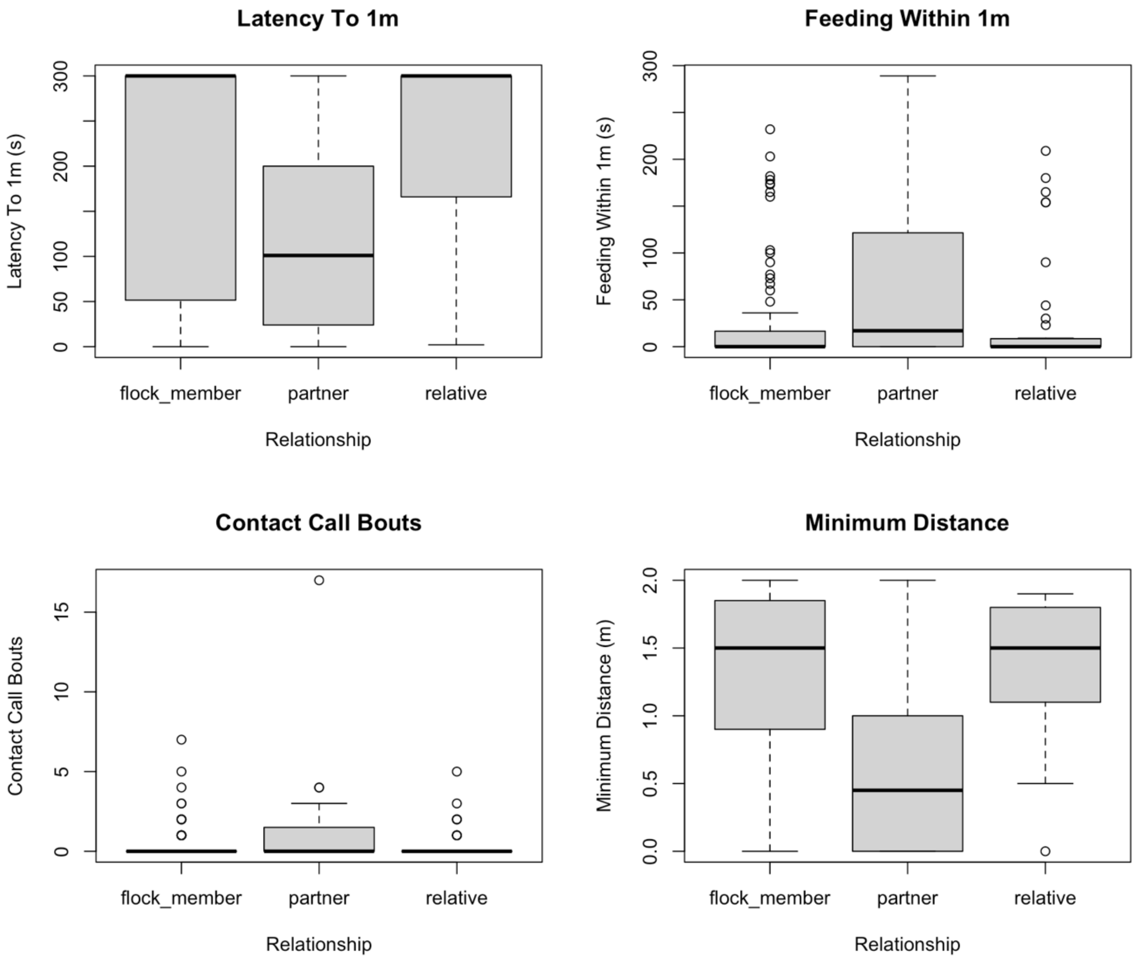

Figure 8: Breeding Season (2023) & Non-breeding Season Data (2021) Combined, Boxplots of photo trials (affiliativ behavior)

Table 5: Breeding Season (2023) vs Non-breeding Season Data (2021), Means & Standard Errors of Photo & Control trials (Affiliative)

Mean & SE	Latency to 1m	Feeding 1m	Call Bouts	Minimum Dist.
Breeding	111.5 ± 12.9	87.9 ± 9.6	1 ± 0.2	1.1 ± 0.1
Non-breeding	209.5 ± 9.6	20.4 ± 3.9	0.3 ± 0.1	1.1 ± 0.1

Table 6: Breeding Season (2023) vs Non-breeding Season Data (2021), Means & Standard Errors of Photo & Control trials (Agonistic)

Mean & SE	Vigilance	Long Neck Total	Hissing Total	Pecks/Attacks /Chases Total
Breeding	3.7 ± 0.6	1.4 ± 0.3	1.7 ± 0.4	0.6 ± 0.1
Non-breeding	0.1 ± 0	0 ± 0	0 ± 0	0 ± 0

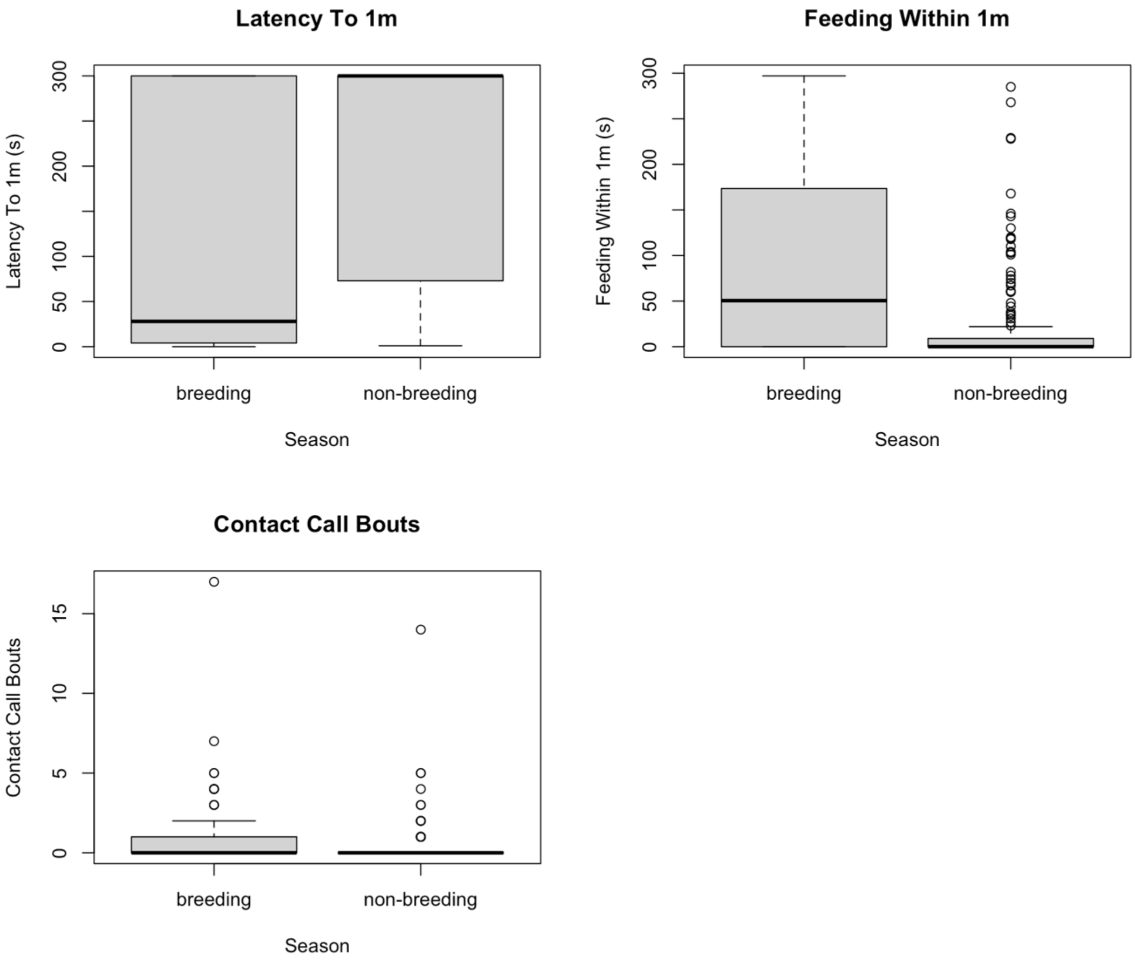

Figure 9: Comparison between breeding season (2023) & non-breeding season dataset (2021), photo & control trials (Affiliative)

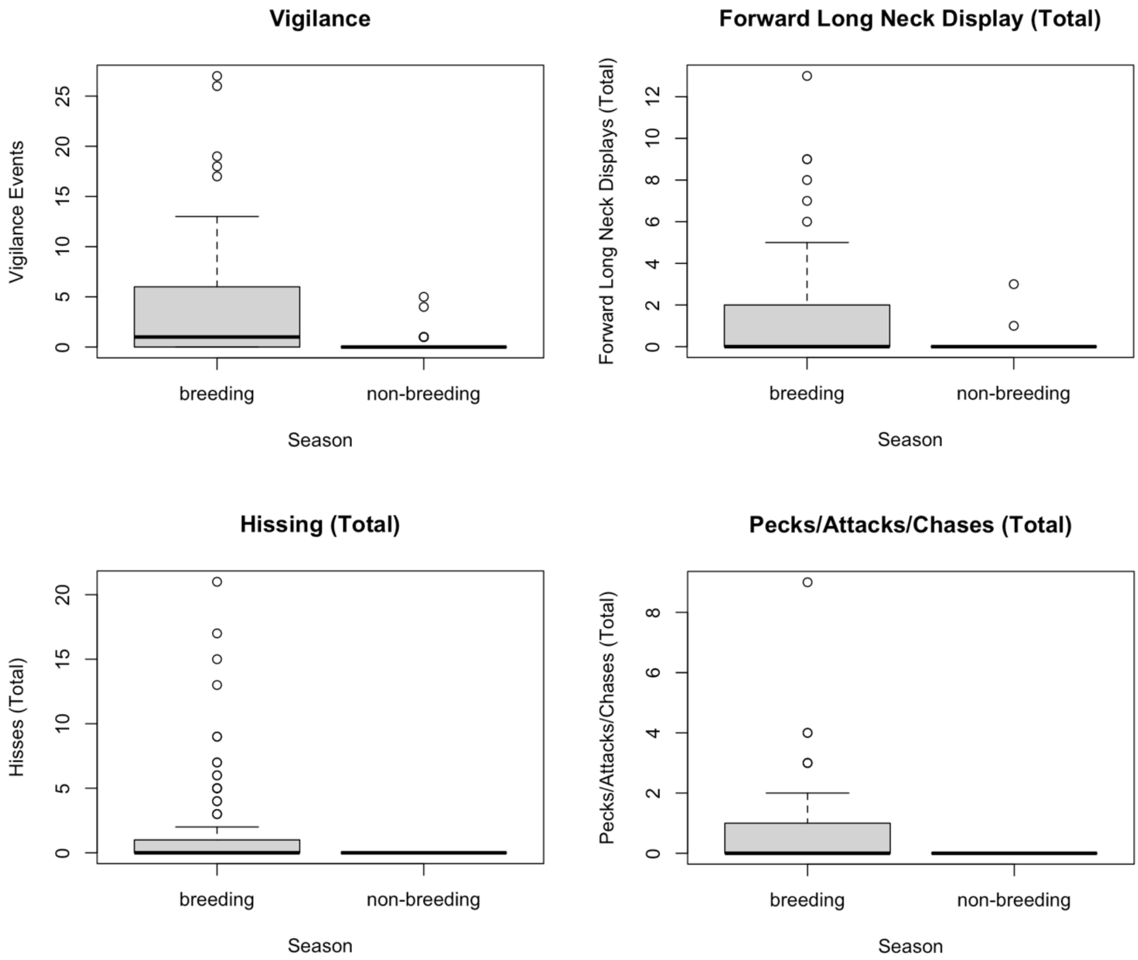

Figure 10: Comparison between breeding season (2023) & non-breeding season dataset (2021), photo & control trials (Agonistic)

Table 7: Breeding Season (2023) vs Non-breeding Season Data (2021), Means & Standard Errors of Control Trials (Affiliative)

Mean & SE	Latency to 1m	Feeding 1m	Call Bouts	Minimum Dist.
Breeding	52.1 ± 17.1	126.9 ± 18	0.6 ± 0.2	1 ± 0.1
Non-breeding	183.1 ± 14.4	32.6 ± 6.8	0.4 ± 0.2	0.9 ± 0.1

Table 8: Breeding Season (2023) vs Non-breeding Season Data (2021), Means & Standard Errors of Control Trials (Agonistic)

Mean & SE	Vigilance	Long Neck Total	Hissing Total	Pecks/Attacks /Chases Total
Breeding	4.3 ± 1	1 ± 0.4	0.8 ± 0.4	0.8 ± 0.3
Non-breeding	0 ± 0	0 ± 0	0 ± 0	0 ± 0

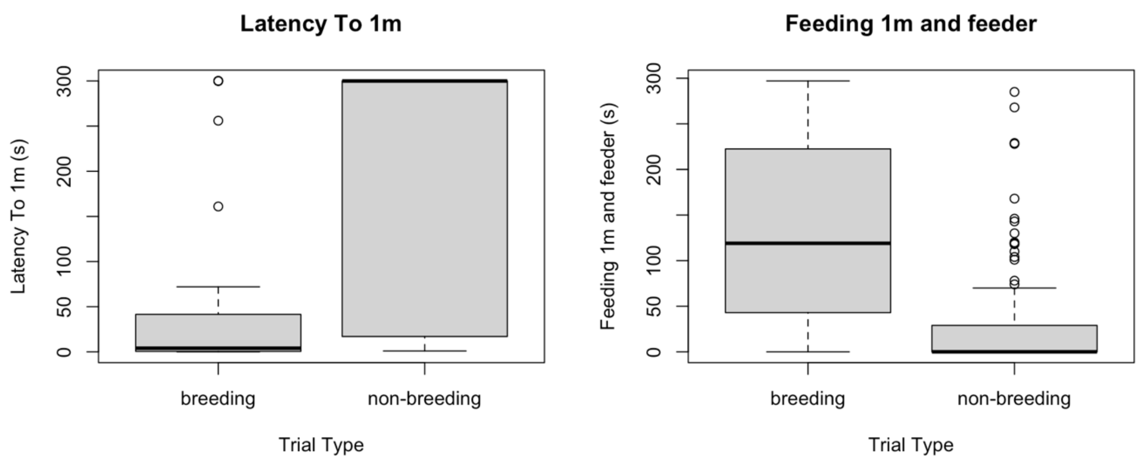

Figure 11: Comparison between breeding season (2023) & non-breeding season dataset (2021), control trials (Affiliative)

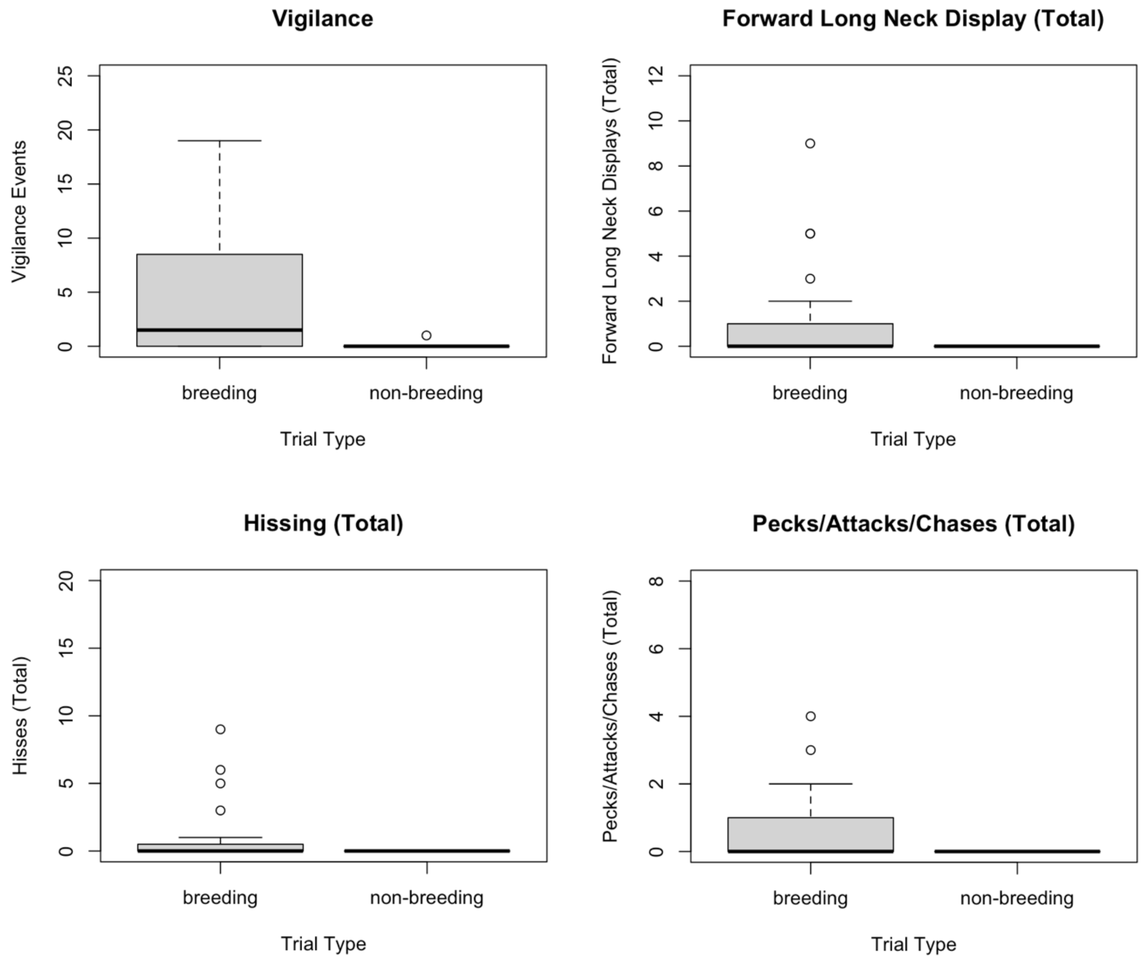

Figure 12: Comparison between breeding season (2023) & non-breeding season dataset (2021), control trials (Agonistic)

Table 9: Means & Standard Errors of agonistic behavior regarding sex

Mean & SE	Sex	Vigilance	Long Neck Total	Hissing Total	Pecks/Attacks /Chases Total
Breeding	Females	0.1 ± 0.1	0.7 ± 0.3	0.2 ± 0.1	0.2 ± 0.1
	Males	5.3 ± 0.8	1.7 ± 0.3	2.4 ± 0.5	0.8 ± 0.2
Non-breeding	Females	0 ± 0	0.1 ± 0.1	0 ± 0	0 ± 0
	Males	0.1 ± 0.1	0 ± 0	0 ± 0	0 ± 0

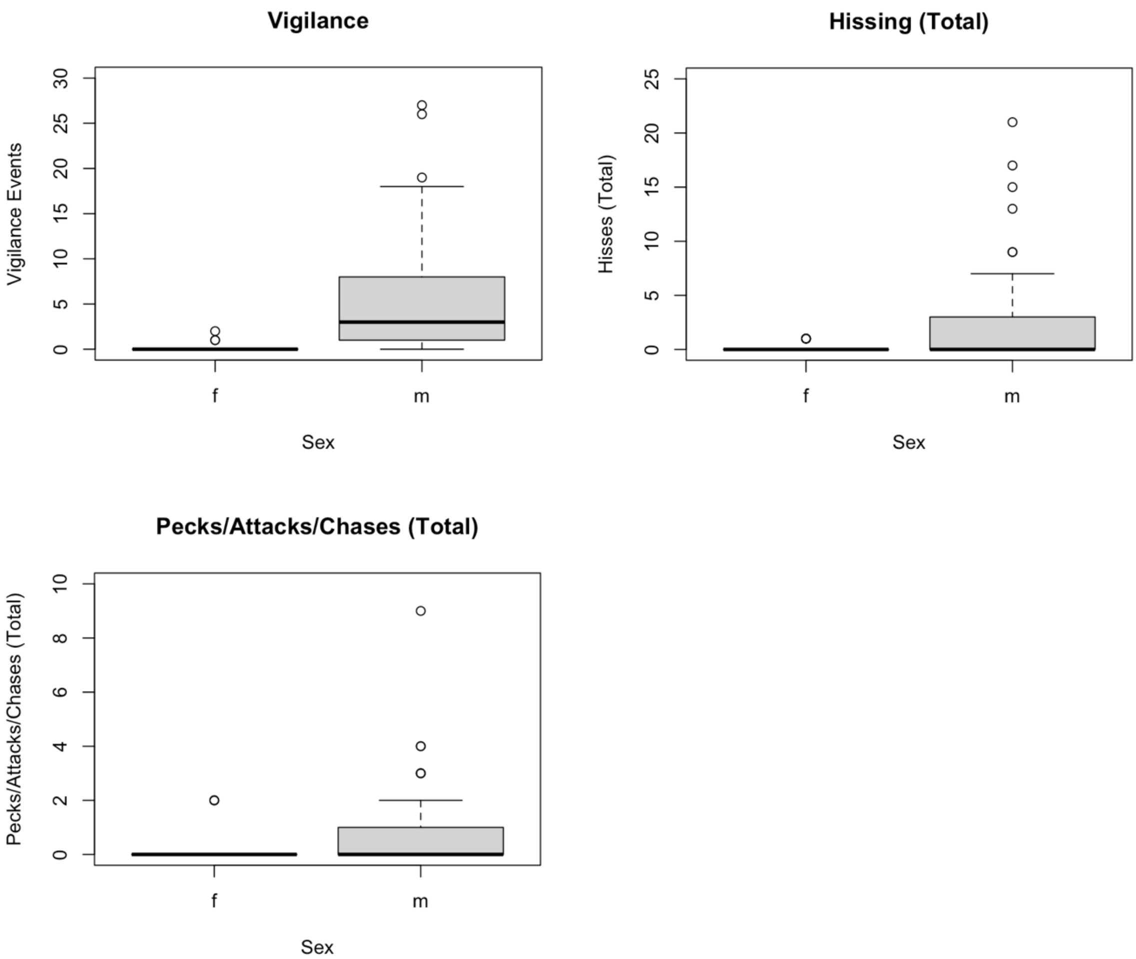

Figure 13: Breeding season dataset (2023) regarding sex (Agonistic)

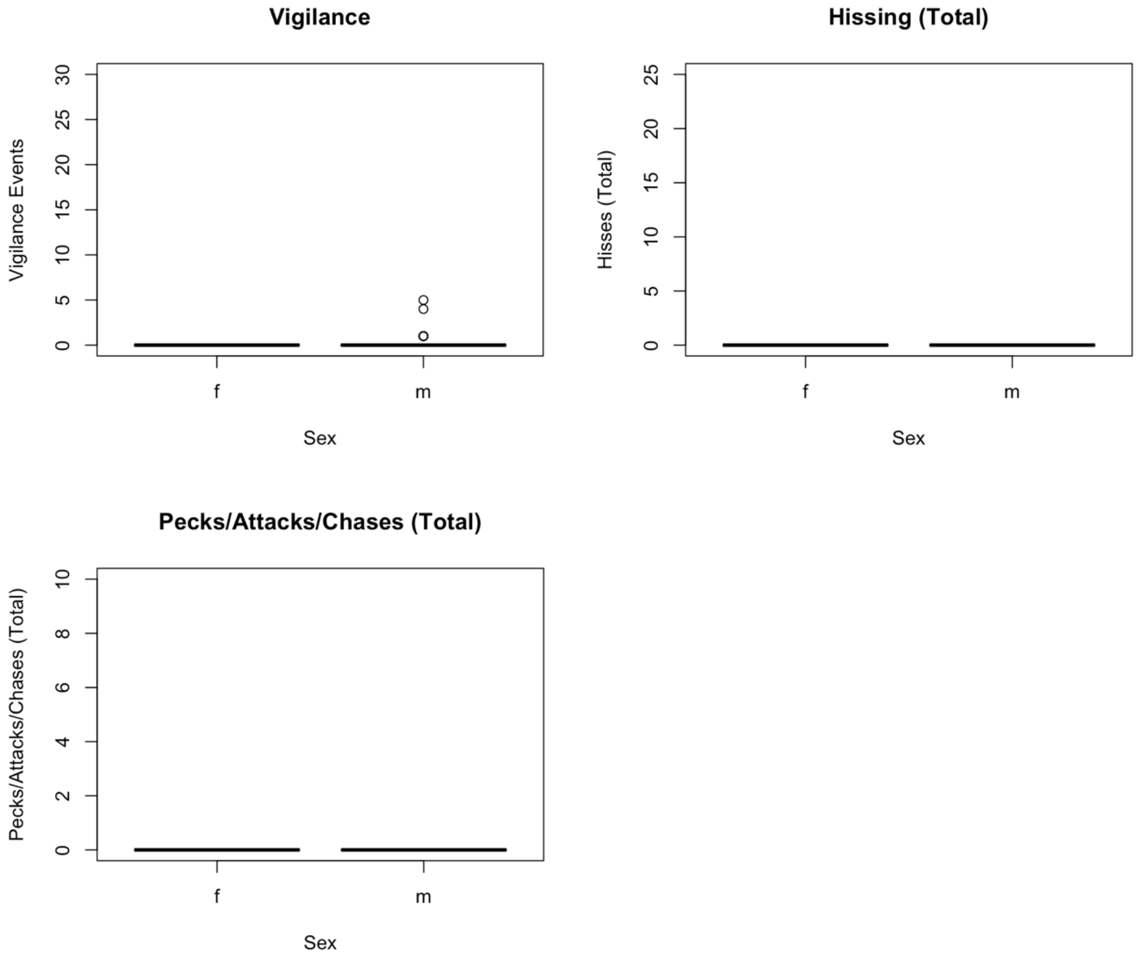

Figure 14: Non-breeding season dataset (2021) regarding sex (Agonistic)

Appendix/Anhang

Abstract

In this study, I investigate visual signaling and visual discrimination in greylag geese *(Anser anser)* during the breeding season and non-breeding season, exploring these widespread phenomena aimed at conveying information, influencing receiver responses and recognizing individuals. Previous research demonstrates such signaling across species, revealing a gap in the understanding of visual discrimination, especially in large, socially complex avian groups. Greylag geese, with their intricate social dynamics and potential for individual recognition, provide an ideal model. I also explore sexual dimorphism, while looking at differences in agonism among these geese. While affiliative and agonistic behaviors in relation to social partners have been observed in various animal groups, it remains unclear if visual discrimination directs these behaviors in greylag geese. Using life-sized photographs of partners, relatives and flock members, I simulate with photo trials, the visual presence of geese and test four hypotheses related to affiliative and agonistic behavior. The results show, geese exhibit differential affiliative and agonistic behaviors in response to photos, appearing to perceive them to some degree as conspecifics. Among the three photo trial types (partner, relative, flock member), the geese showed more affiliative behavior with photos of partners and no difference between photos of relatives and flock members. Moreover, the geese showed higher amounts of affiliation and agonism during the breeding season compared to the nonbreeding season, and males displayed more agonistic behaviors than females. This study sheds light on greylag geese's perception of photos and seasonal and sexual variations in affiliation and agonism, offering potential directions for further research.

Keywords: Visual Discrimination, Greylag geese, Affiliative behavior, Agonistic behavior, Sexual dimorphism

Zusammenfassung

In dieser Studie untersuche ich visuelle Signalgebung und Signalerkennung bei Graugänsen *(Anser anser)* während der Brutzeit und nicht Brutzeit. Hierbei, geht es um verbreitete Phänomene, die darauf abzielen, Informationen zu vermitteln, um die Reaktion des Empfängers zu beeinflussen und Individuen zu erkennen. Vorherige Forschungen zeigen, dass solche Signalgebung bei verschiedenen Arten vorkommt und dabei eine Wissenslücke hinsichtlich der visuellen Erkennung aufdeckt. Dies gilt insbesondere für große, sozial komplexe Vogelgruppen. Graugänse, mit ihrer komplexen sozialen Dynamik und der Möglichkeit zur individuellen Erkennung, bieten ein ideales Modell. Geschlechtsspezifische Unterschiede im agonistischen Verhalten dieser Gänse untersuche ich darüber hinaus ebenfalls. Obwohl affiliatives und agonistisches Verhalten in Bezug auf soziale Partner in verschiedenen Tiergruppen beobachtet wurde, bleibt unklar, ob die visuelle Erkennung dieses Verhalten bei Graugänsen steuert. Mit lebensgroßen Fotos von Partner/innen, Verwandte und Gruppenmitgliedern simuliere ich in einer Reihe von Fotoversuchen die visuelle Anwesenheit von Gänsen und überprüfe vier Hypothesen in Bezug auf affiliatives und agonistisches Verhalten. Die Ergebnisse vermitteln, dass Gänse unterschiedliches affiliatives und agonistisches Verhalten in Reaktion auf die Fotos zeigen und sie diese in gewissem Maße als Artgenossen erkennen. Zudem, zeigten die Gänse während der Brutzeit höhere Mengen an Affiliation und Agonismus im Vergleich zur Nichtbrutzeit, und Männchen zeigten mehr agonistische Verhaltensweisen als Weibchen. Diese Studie wirft ein Licht auf die Wahrnehmung von Fotos bei Graugänsen, sowie auf saisonale und geschlechtsspezifische Variationen im affiliativen und agonistischen Verhalten und bietet potenzielle Richtungen für weitere Forschung.

Stichwörter: Visuelle Signalerkennung, Graugänse, Affiliatives Verhalten, Agonistisches Verhalten, Geschlechtsspezifische Unterschied