LETTER

Personality predicts the use of social information

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Abstract

The use of social information is known to affect various important aspects of an individual's ecology, such as foraging, dispersal and space use and is generally assumed to be entirely flexible and context dependent. However, the potential link between personality differences and social information use has received little attention. In this study, we studied whether use of social information was related to personality, using barnacle geese, *Branta leucopsis*, where boldness is a personality trait known to be consistent over time. We found that the use of social information decreased with increasing boldness score of the individuals. Individuals had lower feeding times when they did not follow the social information and this effect was unrelated to boldness score. When manipulating social information, thereby making it incorrect, individuals irrespective of their boldness score, learned that it was incorrect and ignored it. Our results show that social information use depends on the personality type of an individual, which calls for incorporation of these personality-related differences in studies of spatial distribution of animals in which social information use plays a role.

INTRODUCTION

Individuals constantly need to make decisions such as where to forage, with whom to mate and when to migrate. To decide effectively, individuals rely on information about the potential outcomes of different alternatives. Information might be obtained in two distinct ways: individuals might use personal information, usually retrieved on a trial and error basis by interaction with the physical environment, or they might use information made available by other individuals, which is referred to as social information (Danchin *et al.* 2004). The use of social information has been demonstrated in a wide variety of species (Galef & Giraldeau 2001; Danchin *et al.* 2004; Valone 2007) and is known to affect various important aspects of an individual's ecology, such as foraging, dispersal and space use (Seppänen *et al.* 2007). For instance, in patch selection individuals may use the presence (Drent & Swierstra 1977) or performance (Coolen *et al.* 2003) of other individuals. The role of social information use in the spatial distribution of animals has received considerable attention (see examples in Valone & Templeton 2002; Seppänen *et al.* 2007; Valone 2007), but in nearly all studies to date personality is not taken into

account. This absence reflects a broader phenomenon in ecology, namely that ecologists thus far showed little interest in personality (Réale *et al.* 2007). This is surprising as personality traits may have profound effects on ecological processes like social organization, dispersal and spatial distribution (see studies in Réale *et al.* 2007).

Animal personality describes the phenomenon that differences among individuals of the same species in behavioural and physiological traits are consistent over time and context (Gosling & John 1999; Carere & Eens 2005; Groothuis & Carere 2005). Different behavioural and physiological reactions have a genetic basis (van Oers *et al.* 2005a) and are often phenotypically and genetically correlated. This suggests that these differences are fundamental aspects of the behavioural organization of individuals and are the subject of natural (Dingemanse & Réale 2005; Smith & Blumstein 2008) and sexual selection (van Oers *et al.* 2008).

The relationship between personality and social information use is poorly studied (Marchetti & Drent 2000; Nomakuchi *et al.* 2009) and it is generally assumed that individuals are flexible in their use of social information and that it is context dependent. Consequently, most studies

focus on the conditions under which an animal is expected to use social information (Galef & Giraldeau 2001; Danchin *et al.* 2004; Kendal *et al.* 2005; Valone 2007). Beyond doubt social information use is partly flexible (van Bergen *et al.* 2004; Kendal *et al.* 2004) but there is reason to believe that individuals may consistently differ in the way they process and use cues from conspecifics. First, several studies have demonstrated that shy/slow individuals are more reactive to companions than bold/fast individuals (van Oers *et al.* 2005b; Stöwe & Kotrschal 2007; Harcourt *et al.* 2009), suggesting that shy/slow individuals pay more attention to the behaviour of conspecifics, consequently collecting more social information. Secondly, some studies provide indirect evidence that personality affects social information use: in barnacle geese, *Branta leucopsis*, shy individuals used the scrounging tactic more often compared with bold individuals in a producer scrounger game (Kurvers *et al.* 2010) and in great tits, *Parus major*, fast exploring birds copied the behaviour of tutor birds more readily than slow exploring birds (Marchetti & Drent 2000). Lastly, Beauchamp (2001) showed that in zebra finches, *Taenopygia guttata*, individuals differed consistently in their tactic use in a producer scrounger game with less efficient foragers having higher levels of scrounging (Beauchamp 2006).

To specifically test the hypothesis that shy individual make more use of social information compared with bolder individuals we conducted a social foraging experiment with barnacle geese. Barnacle geese, differing in boldness score, which we use as a proxy for personality (Kurvers *et al.* 2009, 2010), were allowed to watch two pairs of demonstrators which revealed the location of a food resource for the observing goose. After an observation period, individuals were given the opportunity to join one of the pairs, thereby revealing whether they used the social information. In our first experiment, we examined whether geese differing in boldness score used reliable social information in choosing a foraging site. In a second experiment, we manipulated the social information, thereby making it incorrect, whereby we expected that individuals would learn that the social information was incorrect, with shy individuals being the faster learners.

METHODS

Experimental subjects

We used captive-hatched wing-clipped barnacle geese ($n = 20$), each fitted with a uniquely coded leg ring for identification. Birds were sexed by cloacal inspection (13 females, 7 males) and were all unpaired. Before the start of the experiment, we measured tarsus and culmen length (to the nearest 0.1 mm) using callipers and wing length (1.0 mm) using a ruler. Body mass was measured on a digital balance (1.0 g). We used a principal components (PC) analysis of tarsus, culmen and wing lengths to derive a measure of body size. PC1 explained 79.8% of the variation. Body condition was calculated as the residual from a regression of body mass on PC1. When not used for the experiment, all geese were kept as one group in an outdoor aviary of 12×15 m at the Netherlands Institute of Ecology in Heteren, the Netherlands. Throughout the experiments, geese were fed *ad libitum* with a mixture of grains and pellets. A pond (6×1 m) was present in the aviary, with continuous flowing water for bathing and drinking.

Dominance

To establish the dominance hierarchy, we scored agonistic interactions in the flock (December 2007, for details see Kurvers *et al.* 2009). In total, we scored 474 interactions (mean number per individual: 55.6; range: 27–86 interactions). The value of Kendall's linearity index ($K = 0.61$, $P < 0.001$), Landau's index and the corrected index of the sociometric matrix were high ($h = 0.62$, $h' = 0.65$, $P < 0.001$), allowing the use of a linear order to rank the individuals. Individuals were used either as observers or as demonstrators in the social information experiment (see below) based on the dominance hierarchy. Individuals lowest in rank ($n = 8$, all females) were used as demonstrators to assure that observers ($n = 12$) would not be aversive to use information provided by the demonstrators.

Boldness test

We used a novel object test to assess boldness (see for details Kurvers *et al.* 2009). We habituated individuals to an experimental arena. After habituation, we placed a novel object in the middle of the arena, introduced each goose for 10 min and scored the minimal distance reached between the goose and the novel object, as well as the approach latency. We tested each individual twice in February 2008 and twice in November 2008. We calculated PCs of the test variables for each test as an independent measure of novel object score. We use the term 'boldness' for the reaction towards a novel object, although sometimes the term 'exploration' is used (e.g., Réale *et al.* 2007), as we think that the term boldness describes the willingness to take risks in absence of a food reward.

Social information experiment

We used a test arena with an observer area, and two demonstrator areas (see Fig. 1 for details). This arena was built inside a greenhouse to minimize external disturbance. Based on the dominance hierarchy individuals were used as either demonstrators (subordinates, $n = 8$) or observers
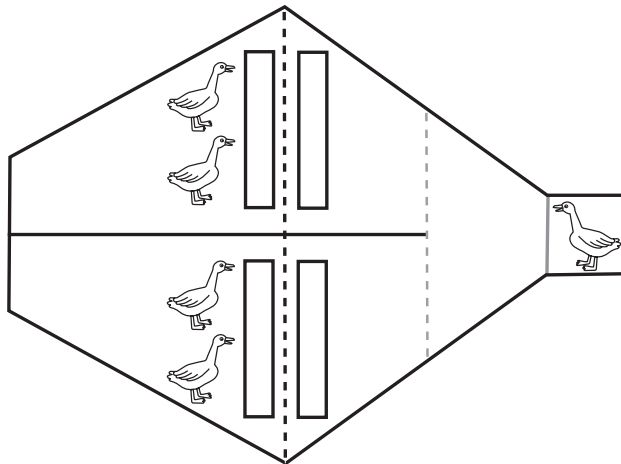
Figure 1 Schematic overview of the experimental arena used for the social information experiment. The closed lines represent a wire fenced with white plastic. The black dashed line represents a wire netting. The goose on the right hand side was the observer goose and was allowed to watch the behaviour of the two pairs of demonstrators before choosing a side. The grey line represents a Plexiglas partition which was pulled up after the observation period (90 s). The grey dashed line represents a taped line on the floor and was used as the criterion of which side the observer chose. The rectangles represent troughs that either contained food or were empty. For the first experiment, we filled one of the troughs of the demonstrators and the observer could find the food on the same side (e.g., both the upper troughs filled). For the second experiment, we filled one of the troughs of the demonstrators but the observer could find food on the opposite side (e.g., the upper left trough and the bottom right trough filled). For the third experiment, (control) we filled no troughs of the demonstrators and one trough for the observer.

(dominants, $n = 12$). An observer was allowed to watch two pairs of demonstrators behind a Plexiglas partition. After 90 s, we allowed the observer to join one pair of demonstrators (the one of its choice) by pulling up the partition (from outside the greenhouse as to avoid disturbance). After joining one of the demonstrator pairs, individuals were able to switch to the other side, but they had to walk around a fence to get to the other side (see Fig. 1). The trials were ended 90 s after pulling up the partition. The observer and the demonstrator areas were separated from each other by wire netting and both pairs of demonstrators were visually isolated from each other by opaque plastic. Each pair of demonstrators had one trough ($10 \times 100 \times 10$ cm) which either contained food or was empty. The observer had two different troughs to choose from, one on each side and in front of one of the demonstrator troughs (see also Fig. 1). We used commercially bought sods of perennial ryegrass, *Lolium perenne*, cut to a height of 1 cm as food. This grass is an important food source for wild barnacle geese (Prins & Ydenberg 1985).

During the experimental period, geese were only offered grass during the experiments (and grains and pellets for the rest of the day). If given a choice barnacle geese show a strong preference for grass as food over grains or pellets (R.H.J.M. Kurvers, H.H.T. Prins, S.E. van Wieren and R.C. Ydenberg, personal observation). Geese were well motivated to consume their preferred resource during the experiments. The demonstrators, for instance, foraged nearly continuously when they had a filled trough.

Prior to the experiment, we trained all demonstrators to start foraging upon introduction in the arena. Demonstrators were introduced in fixed pairs ($n = 4$ pairs) in the experimental arena offering always food in their troughs the first days. Thereafter, we provided food in only half of their entries to habituate them to the condition that food would not always be present. We always used two extra individuals (not used in the remainder of the experiment) as observers to habituate the demonstrators to the presence of a conspecific in the observer area and the lifting of the Plexiglas partition. Demonstrators were introduced at least 20 times in the experimental arena prior to the experiment. Observers were also trained to habituate them to the experimental conditions. First, we introduced each observer four times in groups of six geese in the arena, followed by introducing them four times in the arena in groups of three. In half of these eight introductions food was provided on one side and in the other half on the other side to familiarize the observers with the unpredictability of the location of the food. We placed one demonstrator (individuals not used in the remainder of the experiment) on each demonstrator location without food to habituate the observers to the presence of conspecifics.

During the experiments, we randomly assigned one side as the 'food side' each day, with the condition that we had a maximum of two consecutive days with the same 'food side' and the condition that in each experiment (see below) both sides were in total equally often used as 'food side'. Each demonstrator pair was used an equal number of sessions during each experiment. In each experiment, we balanced the appearance of the demonstrator pairs in such a way that each observer met each pair of demonstrators an equal number of times, equally divided between encounters with and without food to prevent any association between demonstrator pair and food presence.

Experiment 1: correct social information
To test the relationship between personality and the use of social information we provided the pair of demonstrators on one side with food, whereas the pair on the other side faced an empty trough. In the observer area, food was provided in the trough at the same side as those in the demonstrator area. In this situation, the information provided by the demonstrators was completely correct showing the actual

place of the accessible food. We tested 12 observers, differing in boldness score, once per day for a period of 12 days and scored whether the observer followed the social information (i.e., joined the foraging pair) identified as entering one of the two demonstrator pair compartments by crossing a line (see also Fig. 1) (7–21 April 2008).

To investigate the possible cost of a loss of feeding time when making an incorrect decision and whether this cost varied for individuals of different boldness scores, we also scored feeding time defined as the total time an individual had its head in the filled trough.

As individuals were used multiple times in this experiment there was a possibility that an individual formed a routine. We therefore tested for each trial whether the individual chose the same side as it had chosen the previous day. If individuals often chose the same side in subsequent trials, we assume that they formed routines.

Experiment 2: incorrect social information

To test, if observers were able to assess the reliability of social information, we again provided only one pair of demonstrators with food. In contrast to experiment 1, the observer received food in the trough situated at the side of the demonstrator pair that received no food. The information given by the demonstrators was thus consistently incorrect. We used the six most successful individuals from experiment 1 (average success rate: 9.17, range 7–11) as the other six individuals did not follow the social information so testing their reaction towards incorrect information would be irrelevant. We tested the six observers once per day for a period of 12 days and scored whether the observer followed the social information (i.e., joined the foraging pair) (23 April–4 May 2008).

Experiment 3: no social information

Lastly, we performed a control experiment to test if observers could locate the food without receiving any social information. Both pairs of demonstrators did not receive food and the observers received food on one side. We tested six observers (the same as used in experiment 2) once per day for a period of 8 days. We scored if the observer chose the side where we provided food (6–15 May 2008).

Statistical analysis

To test whether observers followed the social information in experiment 1 we used 'choice of the observers' (left/right) as a response variable in a generalized linear mixed model (GLMM) with binomial errors and a logit-link function. As fixed effect we fitted 'food side' (the social information).

To test the effect of personality on the use of social information in experiment 1 we used 'correct choice' (yes/no) as a response variable in GLMMs with binomial errors and a logit-link function. As fixed effects we fitted boldness score as well as body condition, day, side chosen by the observer, the identity of the demonstrator pair with food, and the interaction between boldness score and day. A significant interaction between boldness score and day with a negative estimate would imply that shyer individuals use more social information than bold individuals over time which, in turn, would suggest the presence of social learning.

We used a paired *t*-test to compare the average feeding time when individuals chose correctly and chose incorrectly. We correlated the percentage of feeding time lost per individual when choosing incorrectly (feeding time incorrect divided by feeding time correct) with boldness score using a Pearson correlation coefficient.

To test whether there was an effect of boldness on choosing the same side as the previous day we used 'choosing same side as previous day' (yes/no) as a response variable in GLMMs with binomial errors and a logit-link function. As fixed effect we fitted boldness score.

To test if individuals would continue following the social information in experiment 2 we used 'choice of the observers' (left/right) as a response variable in GLMMs with binomial errors and a logit-link function. As fixed effects we fitted 'food side demonstrators' (the social information) and boldness score. As there could be a learning effect, we also included period [two levels (1: first half of the experiment; 2: second half of the experiment)] as a fixed effect and the interaction between period and 'food side demonstrators'. A significant interaction would indicate that the effect of the social information on the choice of the observers would be different between the first and the second half of the experiment. In addition, we included the interaction between boldness score and period. A significant interaction would imply that there were differences in learning between individuals of different boldness scores.

We tested if geese were able to establish the location of the food without social information in experiment 3, by using 'choice of the observers' (left/right) in GLMMs with binomial errors and a logit-link function. As fixed factors we fitted boldness score and 'food side'. A positive effect of 'food side' would indicate that the observers could establish the location of the food without using the social information provided by the demonstrators.

In all mixed models we also included 'food side previous day' as a fixed effect. A positive significant effect would indicate that the observers used information from the previous day ('personal information'). To avoid pseudoreplication, we included observer identity as a random effect in all mixed models. For all models, we started with full models containing all terms. Minimal adequate models were obtained by stepwise deletion of non-significant terms ($P > 0.1$), starting with the least significant term. To compare the explanatory power of two subsequent models,

we used a log-likelihood ratio test which follows a chi-square distribution. We used the package lme4 for mixed model procedures in R (version 2.7.2).

RESULTS

Boldness test

For all four novel object tests PC1 explained between 76 and 90% of the variation. The correlations of both the minimal distance and the approach latency with PC1 were negative, implying that high values of PC1 correspond to bolder individuals. All loading factors were between −0.89 and −0.95 indicating that both measurements are highly correlated with PC1 and that loading factors were similar across trials. Repeatability of novel object score was high (0.72 over the four tests; see also Kurvers *et al.* 2009) indicating that individuals differed consistently in their boldness scores. We averaged the four measurements of novel object score to derive a composite boldness measure for each individual.

Correct social information

There was a significant positive effect of social information on the choice of the observers ($\chi^2 = 12.92$, $P < 0.001$): over 12 days observers joined 89 times the demonstrators which received food and 55 times the food deprived demonstrators (Fig. 2a), indicating that the observers followed the social information. There was no effect of 'food side previous day' ($P > 0.1$). There was a negative effect of boldness score on social information use ($\chi^2 = 8.23$, $P = 0.004$; Fig. 3): the number of times the observer joined the demonstrators which received food increased with decreasing boldness score of the observer,
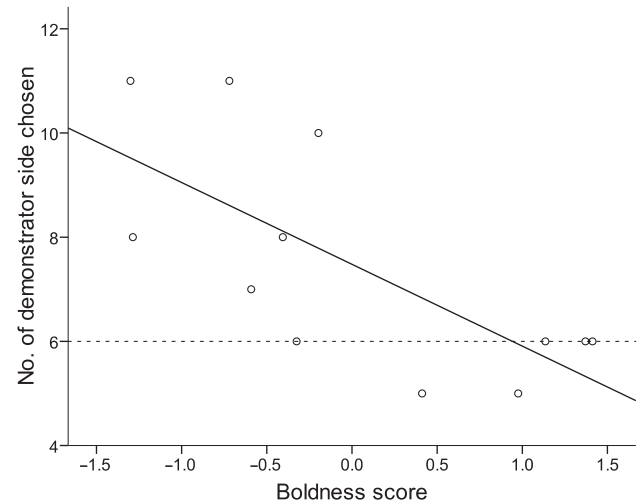

Figure 3 Social information use decreased with increasing boldness. Successful joining of foraging demonstrators decreased with increasing boldness during experiment 1. Shown are the total number of times each observer goose ($n = 12$) joined the foraging demonstrators. Dashed line represents expectation based on random choice.

implying that shyer individuals made more use of the available social information. There was no effect of body condition, day, side chosen by the observer and the identity of the demonstrator pair with food (all $P > 0.1$). Moreover, there was no significant interaction between boldness score and number of days since the start of the experiment ($\chi^2 = 0.01$, $P > 0.9$).

Individuals had higher feeding times when choosing correctly (mean ± SD = 25.4 ± 12.0 s) than when choosing incorrectly (8.1 ± 7.7; $t_{11} = 4.83$, $P = 0.001$). There was no significant correlation between boldness score and
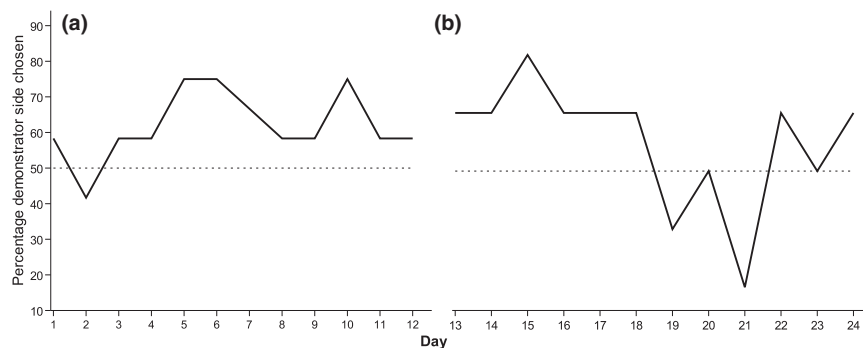

Figure 2 (a) Results of experiment 1 where the food for the demonstrator and the observer were on the same side (correct social information). Shown are the percentages per day individuals chose the side where demonstrators were foraging/which contained food over a period of 12 days ($n = 12$). (b) Results of experiment 2 where the food for the demonstrator and the observer were on the opposite side (incorrect social information). Shown are the percentages per day individuals chose the side where demonstrators where foraging/which did not contain food over a period of 12 days ($n = 6$). Dashed line represents expectation based on random choice.

feeding time lost when choosing incorrectly ($r = 0.43$, $P = 0.16$).

There was a positive effect of boldness on the number of times individuals chose the same side as they chose the previous day ($\chi^2 = 5.81$, $P = 0.016$).

Incorrect social information

There was a significant period-'food side' interaction on the choice of the observers ($\chi^2 = 4.33$, $P = 0.038$; Fig. 2b), indicating that there was a different effect of the social information on the choice of the observers between the first and the second half of experiment 2, so we tested both periods separately. In the first half of the experiment, there was a significant positive effect of social information on the choice of the observers ($\chi^2 = 9.25$, $P = 0.002$), indicating that the observers continued to join the demonstrator pair which received food (i.e., followed the social information) (day 13–18 in Fig. 2b). In the second half of the experiment, there was no effect of social information on the choice of the observers anymore ($\chi^2 = 0.68$, $P = 0.41$), indicating that the observers did not join the demonstrator pair which received food more often than the pair which received no food (day 19–24 in Fig. 2b). In all models, there was no effect of 'food side previous day' (all $P > 0.1$). Additionally, there was no significant interaction between boldness score and period ($P > 0.7$) and no effect of boldness score ($P > 0.2$).

No social information

There was no effect of the presence of the food on the side chosen by the observers ($\chi^2 = 0.82$, $P = 0.37$; Fig. 4), indicating that the observers were not able to establish the location of the food without the presence of any social information. There was no effect of 'food side previous day' and no effect of boldness score (all $P > 0.1$).

DISCUSSION

Our results show that the use of social information decreased with increasing boldness. This result is particularly striking, given that the observers were only able to collect social information, as it was impossible for observers to collect personal information during the observation period (as was revealed by experiment 3). Moreover, the information in experiment 1 was completely reliable and there was no cost associated with collecting social information and no cost of aggression (as the observers and demonstrators had separate troughs and all the observers were dominant over all demonstrators). Importantly, we were able to discriminate between the use of social information and the motivation to be close to conspecifics ('sociability') as both
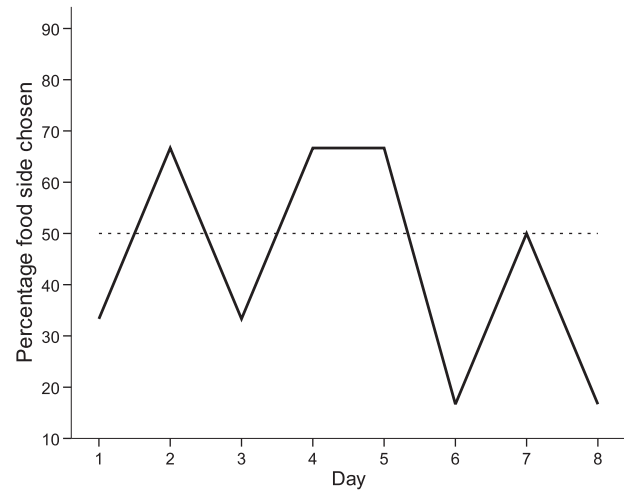

Figure 4 Results of experiment 3 where there was no food for the demonstrators and food on one side for the observers (no social information). Shown are the percentages per day individuals chose the side which contained food over a period of 8 days ($n = 6$). Dashed line represents expectation based on random choice.

demonstrator pairs were of the same group size. It has been shown that shy individuals have a stronger tendency to stay close to conspecifics (Budaev 1997; Ward *et al.* 2004; Michelena *et al.* 2008) making it difficult to judge whether a higher use of social information by shy individuals is merely the result of their higher tendency to stay close to others, or whether it is an active strategy (Sih & Bell 2008; Kurvers *et al.* 2010).

The observation that individuals within a species differ in their reaction to social information can have important implications for the spatial distribution patterns of individuals. Most models on spatial distribution patterns of individuals assume that each individual has an equal chance of being attracted to conspecifics or pay equal attention to the behaviour of conspecifics. Our observation that personality affects social information use and the many recent examples of the presence of personality in a wide variety of species (Gosling & John 1999; Koolhaas *et al.* 1999; Carere & Eens 2005; Groothuis & Carere 2005) questions this general assumption and stresses the need to include consistent behavioural variation in models of the spatial distribution of a species.

When studying group formation processes it is often difficult to reveal the exact reason for social attraction between individuals. The benefits of joining a group are generally assumed to be an increase in safety and/or an increase in foraging information (Ydenberg *et al.* 1983; Giraldeau & Caraco 2000; Krause & Ruxton 2002). It is often difficult to disentangle for which reason individuals join a flock. For example, in experiment 1, observers could have chosen to join the foraging individuals because they

received information on the food availability of the patch or, alternatively, because they perceived the patch of the feeding demonstrators as safer due to the lower vigilance level of the foraging demonstrators. We were able to distinguish between both alternatives because if observers followed the lower vigilance level of the foraging demonstrator pair then we expected that the observers in experiment 2 continued to join the foraging demonstrators. However, observers decided not to continue joining the foraging demonstrators during the second half of experiment 2 (when the social information was incorrect), indicating that in experiment 1 the observers were using information related to foraging opportunities, ruling out predation avoidance as a motivational factor in our experiment. In the field, it has been shown that barnacle geese are attracted to plastic models of barnacle geese (Drent & Swierstra 1977) and that the posture of the models ('grazing' and 'alert' posture) affects the level of attraction: groups with a higher percentage of grazing models attract more barnacle geese than groups with a lower percentage of grazing models (Drent & Swierstra 1977). This observation suggests that barnacle geese use the posture of other individuals in patch decision rules and we show here that personality can play a role in such patch decision rules and consequently group formation and composition processes. The question, however, remains why individuals within one species differ in their social information use.

First, bolder individuals might have had a lower loss of feeding time when choosing incorrectly as bolder individuals are known to explore the environment more readily. Individuals indeed lost feeding time when they chose incorrectly, but there was no effect of boldness score on feeding time lost indicating that our observed relationship between boldness and social information use is not due to an absence of costs for bolder individuals. Secondly, bolder individuals may form routines more quickly, thereby neglecting social information around them. Several studies show that more explorative/proactive individuals (Benus et al. 1990; Verbeek et al. 1994; Koolhaas et al. 1999; Carere et al. 2005) are more prone to form routine like behaviour. In agreement with these studies, we found that the probability that individuals chose the same side as the previous day increased with increasing boldness, suggesting that the bolder individuals formed more routine like behaviour, whereas shyer individuals depended more on the social information and were more flexible in their side choice. This suggests that in a field situation bolder individuals may rely more on previous experiences/information, whereas shy individuals rely more on social information. Individual variation in social information use may be maintained by a frequency dependent selection process, whereby a given tactic does better when it is rare in a population. For instance, the individual benefits of using

social information are expected to be higher when fewer individuals are using the same information (e.g., in a producer scrounger context). The next step would be to test our observed variation in social information use in a field situation to study the ecological implications in terms of movement behaviour and fitness consequences.

Few other studies have examined the relationship between social information use and personality. Marchetti & Drent (2000) found that birds selected from fast exploring lines copied the behaviour of tutor birds faster than slow birds. Similarly, Nomakuchi et al. (2009) found evidence that in three-spined sticklebacks, *Gasterosteus aculeatus*, fast explorers used social information to a larger extent by following informed demonstrators further through a maze. The key difference with both these studies is that in our study individuals were allowed to watch the behaviour of other individuals and hence were, during that time, not able to collect personal information, whereas in the previous studies individuals were given the opportunity to collect personal information from the start of the experiment. Additionally, we were able to separate the effect of social information use and sociability (flocking tendency), which was not possible in both previous studies.

Few studies have investigated the role of personality in individual differences in learning (Sih & Bell 2008). Pfeffer et al. (2002) showed that more innovative greylag geese excreted higher levels of faecal corticosterone. Corticosterone excretion is a measurement of the stress response of an individual and relatively large corticosterone responses are associated with reactive individuals (Cockrem 2007). In alignment with this, less proactive mice and great tits change their search pattern faster than proactive individuals as a reaction to a change in environment (Benus et al. 1987; Verbeek et al. 1994). However, several studies reported a positive correlation between boldness and learning speed (see Guillette et al. 2009 and references therein). In our experiment 1, we did not find evidence that there was a learning effect over the course of the experiment, as there was no effect of day and no significant interaction between day and boldness score on correct choice. This suggests that our results are not due to a difference in learning speed between bold and shy individuals, but that shy individuals use more social information during the whole course of the experiment. In experiment 2, individuals learned that the behaviour of the demonstrators did not correspond to the location of the food for the observers anymore. This was unrelated to boldness, although the variation in boldness score of the observers in experiment 2 was low. There are some other examples of individuals which stop relying on unreliable social information. Vervet monkeys, *Cercopithecus aethiops*, learned to ignore playbacks of a call of an unreliable signaller (Cheney & Seyfarth 1988). A similar

mechanism has been demonstrated in Richardson's ground squirrels, *Spermophilus richardson* (Hare & Atkins 2001). Our results show that barnacle geese are able to stop relying on social information when reinforcement stopped. However, in the time given, they were not able to reverse the information by going consistently to the opposite side from where demonstrators where feeding.

To conclude, we have demonstrated that the use of social information decreased with increasing boldness. In addition, we have shown that barnacle geese can assess the quality of social information by showing that they neglected the social information if it was not correct anymore. Our results emphasize the importance of including personality differences (or individual variation) in the theory of social information use and challenge the traditional view of social information use as an entirely flexible and context dependent entity. This indicates that personality differences can affect behavioural decisions related to spatial distribution and group formation processes when these are linked to the use of social information in natural populations and therefore calls for incorporation of these personality-related differences in studies of the spatial distribution of animals in which social information use plays a role.

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