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Evidence for Win-Stay-Lose-Shift in Puppies and Adult Dogs

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Abstract

Many organisms encounter situations where they lack information required to successfully exploit a resource. One stable strategy that may be particularly useful is a win-stay-lose-shift strategy, in which an individual continues to perform a behavior that has proven fruitful in the recent past or otherwise shifts to a new behavior. Here we investigate whether domestic dogs (*Canis familiaris*) use a win-stay-lose-shift strategy utilizing data from 326 puppies and 323 adult dogs on a repeated object-choice task. We found a significant effect of previous-trial success on dogs' subsequent search patterns. Specifically, dogs were more likely to shift search locations if they were unsuccessful on the previous trial. These findings suggest that puppies and adult dogs win-stay-lose-shift.

Keywords: win-stay-lose-shift**;** strategies; dogs; evolution

Introduction

Most organisms will encounter situations in which they need to make decisions without sufficient information. In predictable environments animals are expected to sample the environment and tune their behavior accordingly. However, animals will often make decisions without enough information to know which choice is best. In unpredictable conditions animals may default to simple heuristics to guide their choices. One such heuristic is win-stay lose-shift, which has been well documented as a strategy in humans and other species (e.g. Berman, Rane & Bahow, 1970; Levine, 1959; Worthy & Maddox, 2014). Win-stay-lose-shift is an effective learning strategy, because it allows the individual to update their strategy after each new piece of information, which is helpful in navigating a world of uncertain probabilities. Win-stay-lose-shift, and its sister strategy win-stay-lose-sample, have been documented as strategies that allow humans to approximate Bayesian inference without having to perform complex calculations (Bonawitz, Denison, Gopnik & Griffiths 2014).

Organisms may develop a preference for a particular strategy that will maximize reward in their specific ecological contexts. Thorndike's Law of Effect states that "the absolute rate of any response is proportional to its associated relative reinforcement" (Herrnstein, 1970). If a certain behavior is rewarded, the individual will be more likely to repeat that behavior, and if a behavior is not rewarded, repetition will become less likely. When looking at guessing behavior, any species' strategy would likely be dependent on their general experiences, and their predictions about probability, which would be different depending on their ecological contexts.

Indeed, instances of these strategies have been observed in many species, even in experimental contexts. When presented with a guessing situation, some animals will perseverate by repeatedly returning to one location. For example, when foraging, wild pigeons tend to return to established patches repeatedly (Goodwin, 1967). This foraging strategy maps onto their behavior when presented with a simultaneous choice experimentally. In a key-choice task, pigeons were more likely to select a key that was previously rewarded than alternate to a new key (Zentall, Steirn, & Jackson-Smith, 1990). In the case of pigeons, there might be a benefit of returning to a location where they were previously rewarded if there is a higher likelihood of finding food in a place that recently had food. This strategy may be useful when there is a cost to searching, such as a large energy expenditure if the two locations were physically far apart, or if there was a high likelihood that an area with food would have food again. In a simultaneous choice paradigm, in which both locations were present in visual proximity, this strategy appears as a bias towards one; selecting one side and sticking with it regardless of their reinforcement history on that side.

The opposite strategy, constantly alternating choices, could also be beneficial in certain contexts. If, when foraging, resources were often found in small quantities and did not regenerate, maximizing exploratory behavior may be beneficial. This strategy is consistently found in rats. When rats are presented with a T-maze, they are found to constantly shift their choice, a behavior identified as spontaneous alteration behavior (Dember & Fowler, 1958; Richman, Dember, & Kim, 1986; Olton & Schlosberg, 1978). In this paradigm, rats go to the opposite of their previous choice every time regardless of whether or not they were rewarded, suggesting a guessing behavior that prioritizes exploration. For the rats, consistent alternation could be useful to maximize the amount of ground covered, which might be more relevant given that the food the rats eat (e.g., a small cached food store) is not likely to regenerate between visits.

These choice strategies may serve those animals well in certain contexts, but they do not allow for much flexibility. For instance, there might be variability in the likelihood of reinforcement at any given food location. If this is the case, animals might benefit from a strategy that incorporates their previous experiences at a location to incorporate the probability of reward at the given location.

One documented strategy in this vein is win-stay-lose-shift. This strategy incorporates the previous experience at any given location in a simultaneous choice scenario. If the location was previously successful, it will be tried again in the next attempt, but if the location did not yield a reward, it will be abandoned to shift to a different location. This flexible strategy is particularly useful in uncertain or complex contexts because it allows for unstable probabilities, as it is adaptable to changing conditions in an environment (Levine 1975). When foraging, if a location that was previously successful ceases to be successful, the organism could adapt by shifting their behavior to a different location. If one particular location is consistently fruitful, the organism could continue to reap the reward until it is depleted. Because of the lose-shift element, the strategy is easily able to account for errors, as any inconsistency can be corrected within a few repetitions.

Because of its flexibility, and ability to account for varying probabilities, the win-stay-lose-shift strategy is particularly useful in social contexts. If an animal is faced with a situation in which it has to predict the actions of another animal, there will likely be many factors at play, and having a strategy that allows for constantly updating behavior based on new data would be helpful.

In humans, win-stay-lose-shift is often seen in the context of the Prisoner's Dilemma. It is sometimes referred to as "perfect tit-for-tat", because it maximizes success when the participant is unable to predict the other player's decision. As long as the other player is cooperating, the best strategy is to cooperate, but if the other player stops cooperating, the strategy can be updated both for personal benefit, and for maximum cooperation. Unlike tit-for-tat, where a player just copies what the opposing player did previously, win-stay-lose-shift allows for either player to make mistakes, while continuing to optimize their overall strategy for maximum cooperation (Imhof, Fudenberg & Nowak, 2007). The social flexibility facet of the win-stay-lose-shift strategy suggests that it might be useful in social contexts, which could mean this strategy is particularly beneficial for more socially cooperative species.

One species that is a promising candidate for exhibiting win-stay-lose-shift strategies is the domestic dog (*Canis familiaris*). Over domestication, dogs have become a highly cooperative species (e.g., Hare, Brown, & Tomasello, 2002; Miklósi & Topál, 2013), adapted to the human social world (e.g., Ben-Aderet, Gallego-Abenza, Reby, & Mathevon, 2017). In particular, dogs are notable for their human-like sensitivity to cooperative communication (e.g., Kaminski, Schulz & Tomasello, 2012; Téglás, Gergely, Kupán, Miklósi, & Topál, 2012). For instance, previous experiments have found that dogs are able to follow social cues such as pointing to find a hidden reward, and are known to use social referencing by looking back at their human companions during difficult problems (e.g., Lakatos, Soproni, Dóka, & Miklósi, 2009; Riedel, Schumann, Kaminski, Call, & Tomasello, 2008). These abilities have been shown to be present even from a very young age, indicating that dogs might be inherently inclined to be social animals (Bray et al. i*n press*).

In their native ecology, without human intervention, dogs do a good deal of foraging, so there is a possibility that they would have strategies similar to those of pigeons or rats in a guessing context. However, dogs occupy a highly social niche, and having a flexible strategy such as win-stay-lose-shift might be an advantage for a species that has a high need for cooperation and often is faced with choices that vary in probability. For example, if a free-ranging dog is dependent on food from a human source, their foraging technique would have to be based on a complex probability of how often a certain human resource had food, and when it would be available to the dog. To test this hypothesis, we were interested in seeing if dogs would demonstrate win-stay-lose shift strategies in their choice behavior in an experimental setting.

To examine whether dogs use a win-stay-lose-shift strategy or a strategy that is less sensitive to changing reinforcement structures (e.g., constant stay or constant shift), we analyzed a task in which dogs would need to decide between two simultaneously presented objects. We used preexisting data from an experiment in which a treat was hidden under one of two cups out of sight, and the dog was allowed to select one of the cups. This task was initially designed as an odor control task, where the location was pseudo-randomized and dogs should not be able to succeed based on perceptual cues, or reinforcement learning. Other research using similar task designs suggests that dogs are not using odor information to make their decision during these types of experiments (e.g. Hare, Call, & Tomasello, 1998, Agnetta, Hare & Tomasello, 2000, MacLean, Herrmann, Suchindran & Hare, 2017).

If dogs are unable to smell the location of the treat and unable to see the treat being hidden, it remains an open question regarding how they make their decisions about which cup to choose. We investigate this question in the current study, with a specific focus on whether dogs are using win-stay-lose-shift strategies. If dogs use win-stay-lose-shift, their performance on the previous trial should be predictive of their choice on the following trial. Specifically, their likelihood of shifting should decrease with previous success. By studying the choice behavior of both puppies and adult dogs, we also aimed to examine potential developmental changes in response strategies.

Methods

All data in the current study were previously collected as a part of a larger test battery (Bray et al, in press). In the current experiment, we focus on one task from this larger test battery, specifically an "odor control" task originally designed to ensure dogs were not able to simply smell the location of a hidden treat.

Population

All of the dogs tested were Canine Companions for Independence (CCI) Labrador Retrievers, Golden Retrievers, or Lab/Golden crosses. The participants were all part of the CCI assistance dog program, either as assistance dog candidates or dams and sires in their breeding colony.

There were two age groups, puppies and adults. Puppies were dogs tested between 8 and 10 weeks (n=334). There were 176 female puppies and 150 male puppies. Adult dogs were a range of ages, averaging 3.08 years, with a minimum of 0.99 years, and a maximum of 10.8 years (n=323). The adult sample consisted of 210 females and 113 males.

Materials and Testing Setup

All dogs were tested in a room set aside in the CCI training facility, as part of a larger 14-task test battery. Puppies were tested in a slightly smaller fenced off area (183cm x 305cm) within the larger room (421.5cm x 599.5cm).

The materials consisted of two disposable blue Solo^{tm} cups. The cups were placed behind a black occluder made of foam core poster board 20cm tall and 91cm long. The distances from the dog were marked with white paint on a 122cmx183cm black mat. See Figure 1 for full testing dimensions.

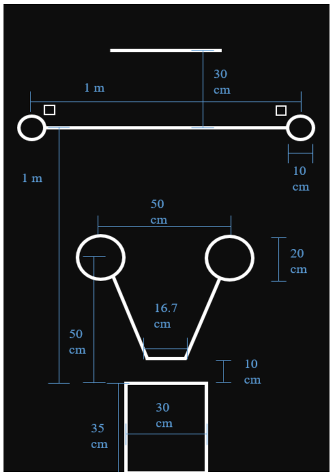

Figure 1: Testing mat.

Food rewards typically consisted of soaked dog kibble from the dog's maintenance diet. If necessary for motivation, some dogs were also offered Zuke's jerky (see test trials for details about when this would occur).

Study Design and Procedure

Dogs first participated in a warmup to introduce the process of finding treats under the cups. Over the course of the warmup, they learned that in order to get a treat from under a cup they must touch it with either their nose or front paws. In order to continue on to the test trials, dogs needed to meet a criterion on warmup trials (Bray et al, in press). Following these warmup trials were two tasks in which dogs were presented with social cues; however, data from these tasks are not presented in this paper. After participating in these social cue tasks, dogs participated in the odor control task which is the focus of the current study.

Figure 2: Dog and cup setup.

The odor control task consisted of 8 trials. It was designed to be pseudo-randomized, so the treat was never hidden on the same side more than twice in a row. The fixed order used across dogs was RRLRLLRL.

To begin each trial, the experimenter knelt on the line 1.65m from the dog and set the cups next to each other behind a black occluder. Participants began each trial 1.45m from the cups. Puppies were held in place by the chest, while adult dogs were on a tab leash, straddled by the handler so that the dog would not be biased to one side or another. The experimenter then presented the treat to the dog, said "Puppy, look!" and placed the treat behind an occluder so the dog could not witness where the treat was hidden. The experimenter lifted both cups behind the occluder and covered the treat with one of the cups as they were set back down. The experimenter then removed the occluder and simultaneously slid the cups to their positions 1m apart while keeping her gaze straight down. The experimenter then put her hands behind her back, saying "Ok," to the dog, at which point the handler released the dog. If the dog did not move, the experimenter repeated the release command up to three times, at which point the dog was nudged directly forward by the handler.

When the dog touched a cup, the experimenter moved the cup so the dog could see what was under it. If the dog was correct, they were praised, and allowed to eat the treat. If the dog was incorrect, the experimenter said "wrong" in a neutral tone of voice and the dog did not receive the treat. Regardless of their first choice, the dog was then restrained by the handler and not allowed to attempt to choose another cup until the next trial.

If the dog did not make a choice within 25 seconds it was scored as 'no choice', and the trial was repeated. If the dog failed to make a choice twice in a row, they were given a set of two refamiliarization trials that allowed the dog to witness the treat being hidden.

If the dog made another set of two consecutive no choices, the dog was then offered a more desirable food reward (Zuke's jerky). If a participant still did not choose after a total of eight refamiliarization trials and being offered more desirable food, that dog was excluded from further participation. No adult dogs were excluded for this reason. Four puppies were excluded after ceasing to choose. In total, 8 puppies were excluded, 4 for not meeting the warmup criteria, and 4 for being unwilling to continue to participate. Therefore, the total number of puppies included for analysis was 326.

Analysis

Our analysis was preregistered on aspredicted.org at https://aspredicted.org/blind.php?x=iq22gh.

As a preliminary analysis, we first confirmed that dogs were not using odor information to determine the hiding location of the treat. To do this, we first conducted a single-sample t-test comparing dogs' overall accuracy to chance. Next, we looked at other factors that might influence dogs' accuracy by running a generalized linear mixed model (GLMM) with trial number and age (puppy or adult) as predictors, and accuracy as a dependent variable, with subject as a random factor. Accuracy in this instance was whether or not the dog was able to correctly choose the cup that the treat was under, and thus the cup that should smell more strongly of a treat. Based on the results from this GLMM, we divided the data into groups based on trial number. We then conducted two single-sample t-tests comparing the dogs' accuracy to chance, to assess whether the dogs were able to learn over trials based on odor information.

To investigate whether dogs were using a win-stay-lose-shift strategy, we then ran a second generalized linear mixed model. This GLMM had age and previous success and their interaction as predictors, and shifting as the dependent variable, with subject as a random factor. Shifting in this case is defined as choosing a location different from the location searched on the previous trial.

Then we conducted a single sample t-test comparing dogs' overall shifting behavior to chance, in order to assess whether they were more likely overall to shift sides or stay with the same side (regardless of the outcome of their previous choice).

To explore the role of individual differences, we conducted all analyses again, excluding dogs that that had 100% side bias (n=103, 44 puppies, 59 adult dogs), 100% constant shift (n=8, all adult dogs), and 100% correct (n=1, an adult dog).

Finally, we conducted one-sample t-tests comparing the proportion of shifts after losses and after wins to chance.

Results

As planned in our preregistration, we conducted a preliminary analysis to examine whether dogs in our sample were relying on odor information to make their choices. Our initial t-test found that dogs did not differ from chance (p = 0.828). In our GLMM, we found an effect of trial number (β= -0.08, SE= 0.01, p <.001), so we divided the data into two groups; early trials (trial 1-4) and later trials (5-8) to assess whether there was a partial learning effect. There is no evidence that dogs were using odor information or learning to use odor information across trials. We did not find a main effect of age or an interaction between age and trial number.

Dogs were above chance on early trials (t(648) = 4.76 p < .001, M = 2.19, SD = 1.00, and below chance in the later trials (t(648) = 6.49, p < .001, M = 1.75, SD= 0.99). This indicates that there was not a learning effect over trials, as dogs were less likely to choose the correct cup in later trials. Given dogs were not exclusively using odor information to make their choices, and were not increasing their accuracy over trials, we continued our analyses to examine other strategies dogs might have been using.

To investigate whether dogs were using a win-stay-lose-shift strategy, we next examined whether dogs' shifting behavior was dependent on their success on the previous trial, and whether it was different across age groups. The results of our GLMM suggest that the dogs were influenced by their previous trial performance (β = -0.58, SE = 0.07, p < .001, OR = 0.56, 95% CI: 0.49, 0.64), such that dogs were more likely to shift when they failed to receive a treat on the previous trial (See Figure 3), with no effect of age.

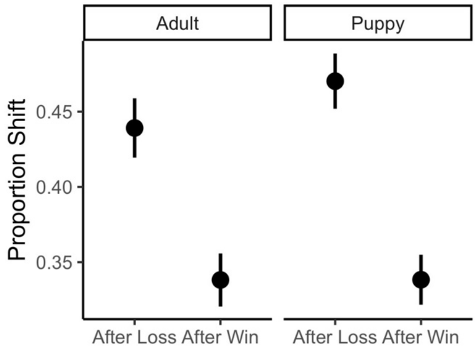

Figure 3: Proportion of shifts after a loss and after a win across both age groups.

In order to assess whether this pattern was driven by a 'stay' strategy after success, a 'shift' strategy after failure, or both – we examined whether dogs were more likely to shift or stay overall, irrespective of their performance on the previous trial. To do this we compared their overall likelihood to shift to chance by conducting a one-sample t-test, and found that dogs were primarily biased to stay on the same side overall, t(648) = 8.01, p < .001.

Individual differences

We then looked for individual differences in strategy. We found 17.25% of dogs were completely side biased (no shifting at all), 1.23% of dogs used a constant alteration strategy, and only one single dog (0.001%) was completely correct, and possibly using odor information. When we excluded these dogs (n=112), we found that the remaining dogs (n=537) did not differ significantly from chance in their shift behavior $t(536) = -1.33$, $p = 0.184$.

We then ran our original analysis again with these dogs excluded and, consistent with our initial findings with all dogs, found a significant effect of previous trial performance ($\beta = -0.53$, SE = 0.07, $p < .001$, OR=0.58, 95% CI: 0.51, 0.67) with no age effects.

Using only the dogs that did not show a side-bias, constant shift, or 100% accuracy, we then conducted a one-sample *t*-test comparing the proportion of shifts to chance. We found that dogs were more likely than chance to shift after a loss $t(533) = 2.63$, $p = 0.009$, m = 0.53, SD = 0.30, but more likely than chance to stay after a win $t(532) = 8.61$, $p < .001$, m = 0.39, SD = 0.29. These finding suggest that dogs are using a win-stay-lose-shift strategy.

With no effects of age in any of the analyses, the findings indicate the use of win-stay-lose-shift emerges early and is stable across ontogeny.

Discussion

We find initial evidence that the majority of puppies and adult dogs are using a win-stay-lose-shift strategy informed by their previous choice in contexts where they lack information about the location of a hidden treat. Specifically, both adult dogs and puppies were more likely to shift to a new location when they were not successful on their previous trial.

Moreover, when examining whether dogs were driven by wins or losses, we found that 17.25% of dogs were using a side-bias strategy, while only 1.23% of dogs used a constant alteration strategy. This suggests that at the individual level, dogs are more likely to stay than shift. After excluding these dogs with 100% stay and/or shift behavior, we found that dogs were more likely to (1) stay after a win and (2) shift after a loss, suggesting that dogs use both the win-stay and lose-shift portions of the win-stay-lose-shift strategy. Thus, although dogs are likely to consistently stay at the individual level, they also show evidence of a win-stay-lose-shift strategy at the group level.

Lose-shifting, may be an important mechanism for an animal to utilize, as it allows for more flexible searching behavior. Not only would this be a useful strategy in a foraging context where the probability of finding food would vary over location, but it would also be particularly useful in cooperative contexts. In a cooperative context, lose-shifting may present as attempting a different strategy for social cooperation after an initial failure, allowing for compromise and maximizing the possibility of cooperation.

Another possibility from the data is that perhaps dogs are naturally at chance with their sampling behavior, but a win greatly increases the salience of a particular side, and therefore increases the likelihood that they will choose that side again on the next attempt. In the fixed order used in this study, there were some cases where the treat appeared on the same side more than once, which could lead to more staying behavior if they are reinforced by a win on that side twice in a row.

The fixed order of trials is one limitation of the current study. Only one order of trials was used in the preexisting data, and it is possible that this stable trial order impacted our findings, as the dogs' experiences would differ depending on their first choice. Future work should further investigate and confirm win-stay-lose-shift strategies in dogs across a wider range of contexts—for instance, randomizing the order of food location, or manipulating the wins and losses directly.

Another limitation is the possibility of reinforcement learning due to the method. Because the dogs were praised when they found the correct treat, the experiment could be placing dogs in a command context, and dogs may be staying with the correct cup in an attempt to perform the task the human experimenter wants them to. However, given that the praise was always paired with a treat, it is unlikely that praise influenced their decision any more than the food reward did. Though we cannot conclusively provide any reasoning for why dogs would use a specific strategy, it is unlikely that praise would alter their choice to stay or shift (Feuerbacher &Wynne 2013).

Moreover, the social implications of this finding also require further examination. Win-stay-lost-shift is a useful strategy when guessing, but its potential for cooperation has implications in game theory problems like the prisoner's dilemma, as well. In these scenarios win-stay-lose-shift is used to maximize cooperation with a partner by altering the strategy based on the choices of the other agent. It is unclear from this design if the dogs are considering the experimenter an agent who is choosing the location of the treat, or if they are simply understanding the scenario as a randomization between two locations with the human experimenter as a facilitator. Given that the current experiment was performed directly following two social cue tasks in which the experimenter acted as a social partner, there is reason to suspect the former explanation.

The implications of the current results would be different whether the dogs are understanding the experimental situation as a game in cooperation with another agent, or a random guessing task. In order to assess which of these possibilities is the case, future work should manipulate human participation, and see if the effect is dependent on the presence of another agent. If dogs are using this strategy to maximize their cooperation with the experimenter, we would expect to find them to employ win-stay-lose-shift when there is an agent, and perhaps revert to side biased perseveration behavior when no agent is present.

To further test the possibility that win-stay-lose-shift strategies might be a useful evolutionary advantage for dogs because of their unique social and cooperative ecology, it will be interesting to examine win-stay-lose-shift strategies in non-domesticated canids as well. Because many canids, like wolves, live in social groups, the win-stay-lose-shift strategy may also be an innate component of their social ecology. However, it is also possible that win-stay-lose-shift is something that has evolved during domestication, as a strategy that would improve inter-species interactions. To test this question, it will be particularly informative to look at win-stay-lose-shift in species such as dingoes and wolves. Other social traits, such as looking back and eye contact (e.g., Johnston, Turrin, Watson, Arre & Santos. 2017; Udell 2015; Passalacqua, Marshall-Pescini, Barnard, Lakatos, Valsecchi & Prato-Previde 2011), have been linked to change over domestication. It will be interesting to see how dingoes and wolves use guessing strategies on a similar task, especially in light of their differences in cooperating with humans.

Though additional work is needed, we provide the first evidence to date that dogs can use a win-stay-lose-shift strategy when guessing, suggesting that dogs might have use for a more flexible guessing strategy to keep up with the complex probabilities of their social environment.

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