Bystander Effects in a Single-player, Anonymous Contest

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1 Introduction

Many animals form large aggregations that have no apparent leader, yet are capable of highly coordinated movements. How this is possible has fascinated biologists for a long time. Which individuals of a group emerge as leaders and why? Often, all individuals of a large group are considered to be equal. But realistically, individuals in a homogeneous group are not all equal and existing differences may affect emerging leadership. Clearly, individuals will differ based on traits like sex, age, and also experience. Of particular interest in this context have been differences in correlated traits, or personalities. Such personalities can arise via complex gene/environment interactions and are often shaped by individual experience.

One very important experience that can influence future behavior is whether or not attempts at leadership are successful or not. Although the effects of personalities and individual experience on leaders and followers is an active area of research [7], we are particularly interested in how individual experience in successful leadership can give rise to leaders and followers when the individuals in a group all share the same personality. There are a variety of systems which can benefit from the improved coordination achieved through effective leadership, such as multi-agent systems, but lack distinct personality types within the group from which leaders and followers naturally emerge. In these artificial systems, it is possible that individual experience can be used to promote the emergence of distinct personality types, which will in turn, lead to the emergence of leaders and followers.

Previous work has shown that this approach can result in the rapid emergence, or differentiation, of distinct personality types and improved coordination in a collective movement behavior that uses winner and loser effects to modify personalities [3]. However, we would like to reduce the number of experiences required for the emergence of distinct personality types to improve overall performance of the group. One way to accomplish this is to maximize the impact of each collective movement experience through bystander effects. Although bystander effects are typically studied in the context of two-player contests [2], we use it in a single-player contest in which an individual attempts to successfully initiate a collective movement. In the work discussed here, we present the results of exploratory simulations on the effects of adding both winner and loser bystander effects to a collective movement model that has been modified and uses personalities to determine leader and follower roles. The simulations predict that contrary to our initial hypothesis, bystander effects inhibited the emergence of distinct personality types.

2 Materials and Methods

The model chosen for this experiment was developed through observations of collective movement attempts in a group of ten white-faced capuchin monkeys [4, 8], and was later confirmed in observations of sheep groups ranging in size from 2–8 members [9]. It uses three interaction rules to govern the decision-making process involved in starting collective movements. The first rule assumes that all individuals within the group can initiate a collective movement attempt. While this assumption may not hold for groups with dominant leaders, studies have shown that it is a viable assumption for egalitarian animal groups, such as the capuchin monkeys used in the model's development.

The second rule describes the rate at which followers join the collective movement attempt. As the number of individuals following the initiator increases, the rate at which individuals join the movement also increases. Note that the model assumes global communication and once an individual initiates a collective movement, the remaining individuals are assumed to have observed the initiation attempt and have the opportunity to follow the initiator.

The third rule describes the fact that not all initiation attempts are successful as initiators often cancel and return to the group. As the number of individuals following the initiator increases, the rate at which the initiator cancels an initiation decreases. Also, simulations of the model include the implicit assumption that a successful collective movement requires all of the members of the group to participate, since there is a non-zero probability of canceling even if all but one member participates. While this is not necessarily the case in nature, cohesive, collective movements are the primary objective of this work and, as such, incomplete movements are considered failures.

Of particular note is the fact that this model assumes that all interactions between individuals are anonymous, meaning individuals in the group are unable to identify the initiator or followers. This assumption differs from common models using bystander effects in which estimating the abilities of others is important in aggression contests [2].

2.1 Adaptive Personality

To investigate the effects of altering the rate at which individuals initiate, follow an initiator, and cancel a movement, Gautrais added a constant, referred to as a "k factor," to the rate calculations of the collective movement model [4]. Since this k factor can either increase or decrease the three decision-making rates for an individual, it was an ideal means with which the effects of personality could be incorporated into the model.

Three important points were considered in integrating personality with the collective movement model. First, personality has been observed in natural systems to affect the events used in this model in different ways. For example, a bold personality should result in a higher initiation rate and lower following and canceling rates, while a shy personality should result in a lower initiation rate and higher following and canceling rates. Second, the magnitude with which a shy personality affects the model should be the same as a bold personality so as not to bias the model towards one personality over another. Since k had a non-inclusive lower limit of 0, the non-inclusive upper limit of 1 was chosen to ensure balance. In the simulations described below, personalities were limited to the range $[0.1 : 0.9]$ to ensure these limits were satisfied. Lastly, although the original model, nor the observations on which the model was based, discuss personality of the individual animals involved, one can assume that the individuals could be classified as having either bold or shy personalities. Therefore, the integration of personality incorporated the concept of a moderate personality ($p = 0.5$) that produced the same results as the original model.

The initiator's personality was updated after every collective movement initiation attempt using the following standard update (or learning) rule [1, 6, 10]:

$$p_{t+1} = p_t(1 - \lambda) + \lambda r \tag{1}$$

where p_t was the initiator's personality for the current movement, p_{t+1} was the personality for the next movement, λ was the rate at which updates changed the personality, and r was the reinforcement value used to update the personality. When λ was low, the personality was primarily determined through long-term historical success and changes were minor. When λ was high, the personality was primarily determined through short-term success, namely the last initiation attempt, and changes from one attempt to the next were significant. For the simulations described in this work, a low value of lambda was chosen ($\lambda = 0.02$) to emphasize long-term initiation success. For successful initiations, the reinforcement was $r = 1$, while it was $r = 0$ for unsuccessful initiations.

Since the simulations assumed global communication through the group, all the remaining individuals in the group were able to observe the initiator, and were thus eligible for bystander effects. Bystander personalities were updated using the same mechanism as the initiator, except that the reinforcement values were switched. That is, a bystander that observed a successful initiator, or a winner, became shyer, while the initiator became bolder. Conversely, a bystander that observed a failed initiator, or a loser, became bolder, while the initiator became shyer. Since true winner and loser effects and bystander winner and loser effects may affect the personality to varying degrees [2], the λ value for bystander effects was independent of the value chosen for the initiator.

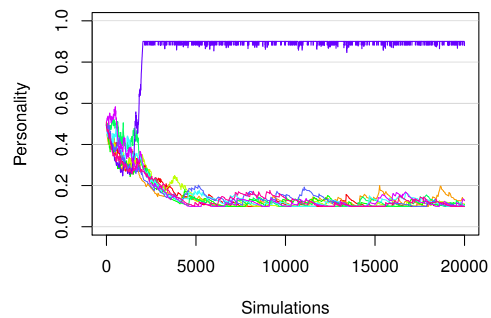
2.2 Numerical Implementations

Numerical simulations of the collective movement model were implemented in Java using the same algorithm as in previous work [4]. The time of each event was calculated as a random number drawn from an exponential distribution using the appropriate rate. As such, the simulations use continuous time events, and not discrete time. Fifty evaluations were performed for each combination of true winner and loser effects and bystander winner and loser effects, each with a different random seed. A single evaluation consisted of 20,000 simulations. Each simulation constituted a single attempt at a collective movement and ended in either success (all individuals participating in the movement) or the initiator canceling. Individual personality values were reset at the beginning of each evaluation and persisted from one simulation to the next. The model parameters used were the same as those used in the original model, including a group size of 10 individuals [4, 8].

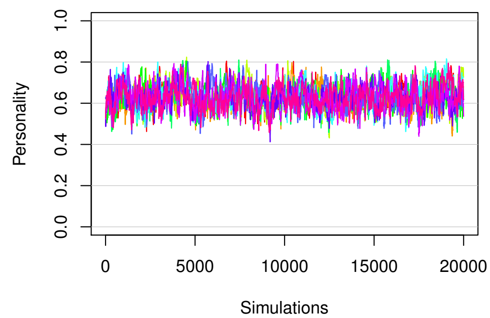
To analyze trends in personality values of successive simulations in an evaluation, the R package `strucchange` was used [11]. This software package allowed for the identification of structural shifts in time series data. In our simulations, these shifts, referred to as breakpoints, represent a personality transition. Since personalities are not constant and the analysis produces a linear approximation of a portion of personality value time series, we defined a personality to be bold if a segment of the personality had a value greater than or equal to 0.775.

3 Results & Analysis

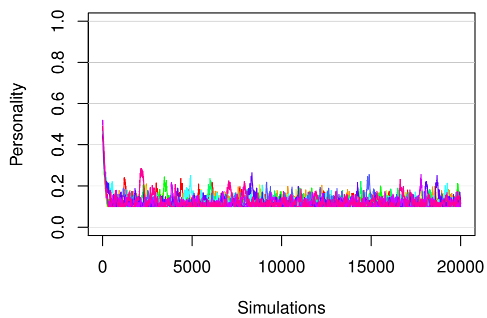
Figure 1 depicts representative personality update histories for each combination of true winner (TW), true loser (TL), bystander winner (BW), and bystander loser (BL) effects simulated. When the λ value used for bystander effects was relatively strong



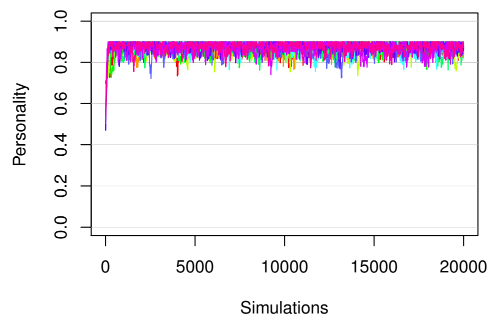
(a) TW, TL (Baseline)



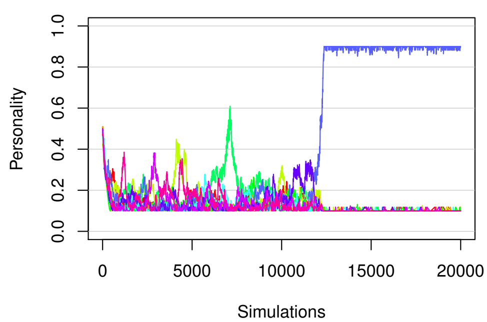
(b) TW, TL, BW (100%), BL (100%)



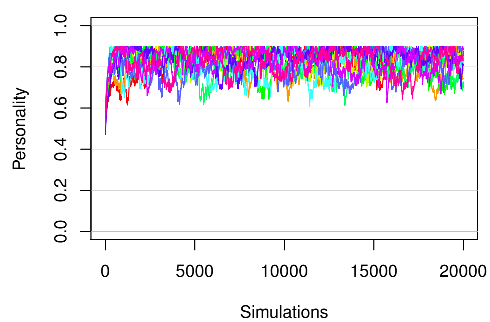
(c) TW, TL, BW (100%)



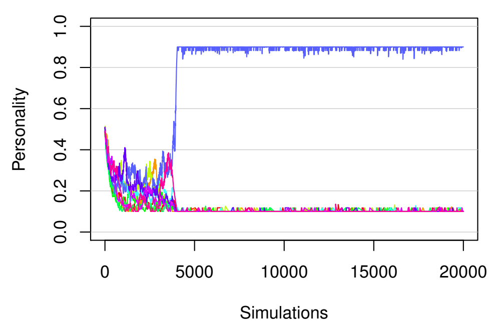
(d) TW, TL, BL (100%)



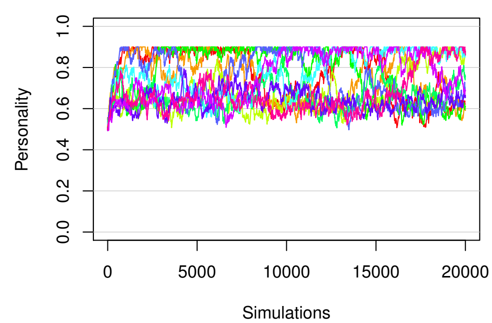
(e) TW, TL, BW (50%)



(f) TW, TL, BL (50%)



(g) TW, TL, BW (25%)



(h) TW, TL, BL (25%)

Figure 1: A representative personality update history is shown for various combinations of true winner (TW), true loser (TL), bystander winner (BW), and bystander loser (BL) effects that were simulated. Bystander winner and loser percentages indicate the strength of λ used for bystander effects relative to the λ used for initiators.

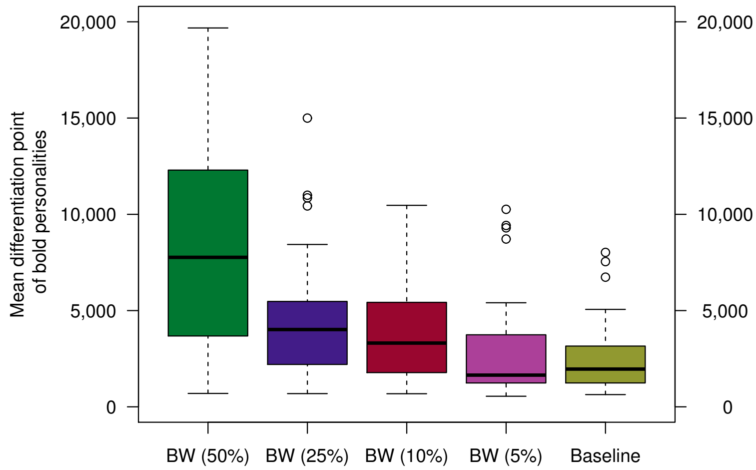


Figure 2: The median number of simulations within an evaluation required for the emergence of distinct personality types is shown for simulations using bystander winner effects only in which distinct personality types emerged. Boxes depict the interquartile range (IQR) from the first quartile to the third quartile over all 40 trials, the horizontal line represents the median fitness value, the whiskers represent the ±1.5 IQR, and the circles represent outlier values.

compared to the λ used for the initiator, the emergence of distinct personality types was inhibited, either with delayed emergence as compared simulations without bystander effects or no emergence at all (see Figures 1c, 1d, 1e, and 1f). However, when bystander winner effects were relatively weak compared to those for the initiator, the emergence of distinct personality types was promoted. Furthermore, these results indicate that follower personalities are more stable with bystander winner effects once distinct personalities, specifically bold leaders, have emerged.

These simulations predict that bystander loser effects are particularly detrimental to the emergence of distinct personality types (see Figures 1b, 1d, 1f, and 1h). This is most likely due to the low success rate for collective movement initiations before distinct personalities have emerged. When failure is common, differentiation into distinct personalities is difficult since all but one of the individuals in the group increases its chance of being a leader through an increase in its personality value. However, since bold personalities are less likely to follow an initiator [5], successful initiations become rarer, creating a feedback loop that inhibits both success and the emergence of distinct personality types.

Figure 2 shows the median number of simulations required for distinct personality types to emerge for simulations using bystander winner effects only. Simulations using the same λ value for both bystanders and the initiator and simulations using bystander loser effects are omitted since little to no distinct personalities emerged. Results of the bootstrapped Kolmogorov-Smirnov test show that for simulations using a λ bystander value of 50% of the initiator's, the median number of simulations required for emergence is statistically significantly higher than the other simulations and the median for simulations using a λ bystander value of 5% of the initiator's is statistically significantly lower than the other simulations using bystander effects with $p < 0.01$. There was no statistically significant difference between simulations using a λ bystander value of 5% of the initiator's and baseline simulations that did not use bystander effects. These results are consistent with the observations of personality histories from Figure 1, namely that in these simulations, bystander winner effects have the potential to prevent the emergence of distinct personality types and do not appear to provide any improvement in the time required for emergence over the baseline configuration with no bystander effects.

Acknowledgments

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