

The evolution of punishment and apology: an iterated prisoner's dilemma model

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Recently, behaviors that seem to function as punishment or apology have been reported among non-human primates as well as humans. For example, in rhesus macaques it was demonstrated that 'deceptive' individuals, which did not emit the call when they discover food, received more aggression from the later-comers than 'honest' individuals did. In most primates, apology-like behavior during post-conflict periods has been reported between former opponents. In populations of real animals, it seems costly to punish or make an apology especially for the subordinate animals because of possibility being attacked. Such punishment-like attacks or apology-like behavior appear to play an important role in maintaining cooperation between individuals. Therefore, the evolution of these behaviors should be examined from the viewpoint of the evolution of cooperation. The iterated prisoner's dilemma (IPD) game is generally considered to be a standard model for the evolution of cooperation. In the present study, strategies accompanied by punishment-like attacks or apology-like behavior were introduced into the common IPD simulation. Punishment and apology were represented by the P signal and the AS signal given immediately after defection. A strategy with the P and AS signals, named the pPAS strategy, was proved to be an evolutionarily stable strategy under certain conditions. Numerical simulations were carried out according to different assigned values of the costs of punishment and apology. The simulations showed that pPAS could dominate the population (1) when the cost of giving P is relatively small, (2) when the cost of receiving P is relatively large, or (3) when the cost of giving AS is relatively large. The relative cost of giving AS had the clearest effect on the success of pPAS. pPAS can dominate the population even when a dominance asymmetry of the costs between two players was introduced. The present results suggest the possible evolution of social behaviors like punishment or apology as a means of maintaining cooperation.