Information Warfare and Evolution

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Abstract

This paper reviews the four canonical strategies of Information Warfare and asserts that Information Warfare is an artifact of evolution in biological systems: the use of Information Warfare techniques by organisms aids survival in a competitive environment. A range of specific biological examples are explored to support this assertion.

Keywords: Information Warfare, Evolution, Survival Strategies

INTRODUCTION

Information Warfare is frequently seen as a 'modern' phenomenon, an extension of often historical techniques of conflict into the 'infosphere', consistent with the Toffler model of post-industrial age societies 'digitising' their economies, governments and militaries. This widely accepted view reflects an implicit association between many of the techniques of Information Warfare, such as *Cyber War*, *PsyWar*, *Electronic Attack*, the supporting environment defined by *Moore's Law* and the phenomenon of Information Warfare itself.

Accordingly, it is often argued, if the phenomenon of Information Warfare is a property of the means used to implement it, then surely it is by nature a contemporary of these means. As the means of implementing Information Warfare are modern, it must therefore be a modern phenomenon.

This argument can be proven to be a basic fallacy. Information Warfare can be shown to be a very fundamental survival technique which has been and is widely used by biological organisms of unusually diverse species.

It therefore follows that the novelty in Information Warfare is wholly in the eye of a beholder. The only novel aspect of the natural phenomenon of Information Warfare is our understanding of it.

This paper will briefly review the fundamental paradigm of Information Warfare, and discuss a number of biological case studies which support this argument.

1. THE FOUR CANONICAL STRATEGIES IN INFORMATION WARFARE

'*Information Warfare is any action to Deny, Exploit, Corrupt or Destroy the enemy's information and its functions; protecting ourselves against those actions and exploiting our own military information functions'.*

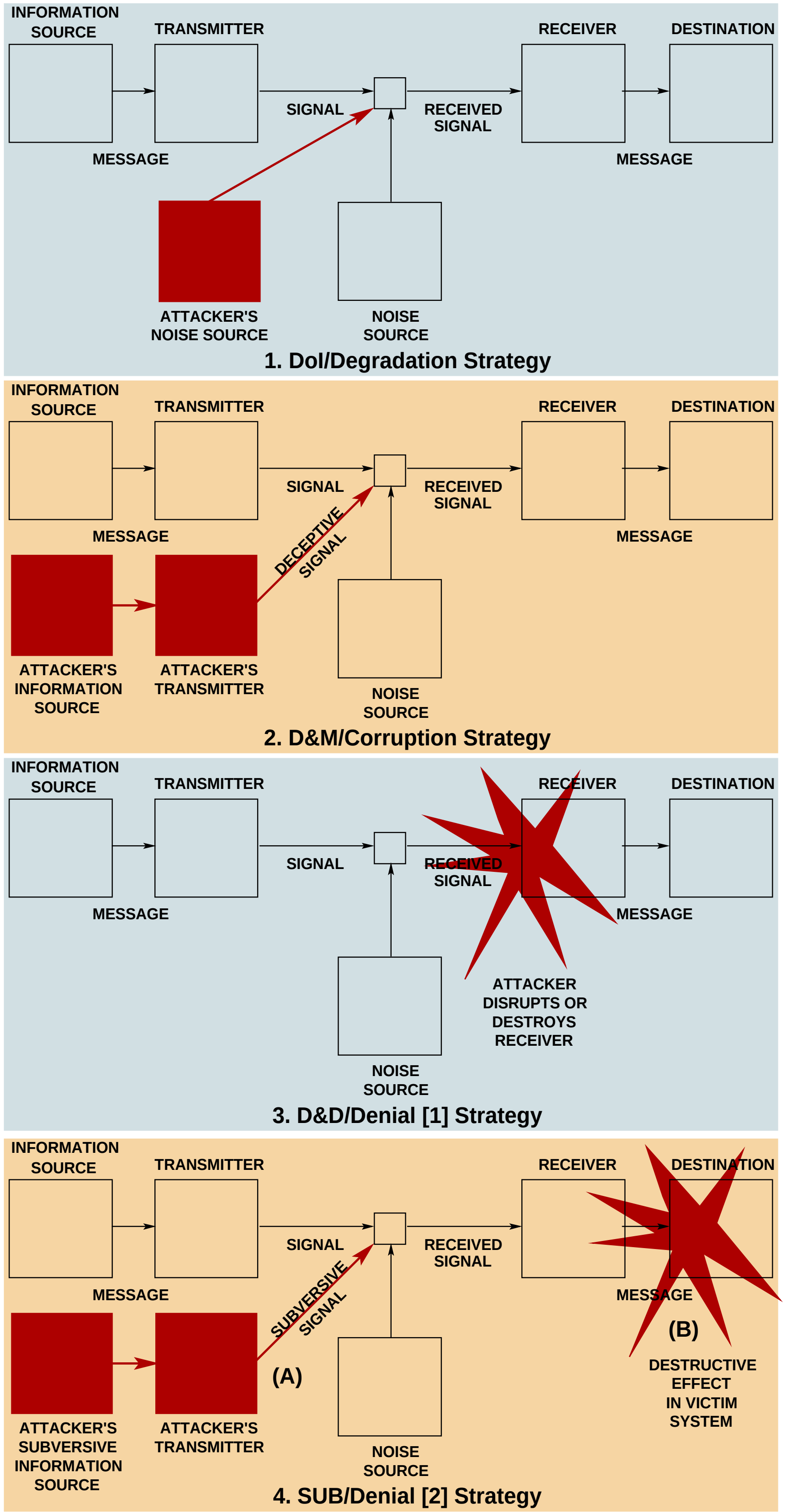

Figure 1: *The four canonical offensive Information Warfare strategies (Author).*

This widely accepted definition is the model asserted by the United States Department of Defence[i] .

It describes Information Warfare in terms of 'actions' executed to achieve a sought outcome - denial, exploitation, corruption and destruction of an opponent's 'information' and related functions, and prevention of such 'actions' executed by an opponent.

These four basic Information Warfare 'actions' can be directly mapped into models based upon Shannon's information theory, refer (Borden, 1999), (Kopp, 2000), or models based upon hypergames[ii] .

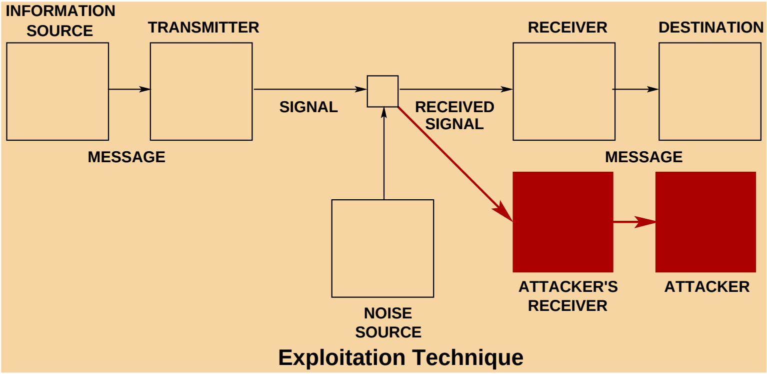

Figure 2: *Exploitation as an Information Warfare technique (Author).*

Four canonical offensive Information Warfare strategies have been identified (Kopp, 2000) and (Borden, 1999), yielding two overlapping models which essentially encapsulate the same effects. Each strategy aims to produce behaviour in the target which is detrimental to the target, or to prevent target behaviour which is of benefit to the target.

An attacker aims to prevent correct processing of information. This may be accomplished either by attacking the information itself, or by attacking the processing of that information. Orthogonally, the attacker may either degrade or corrupt what it attacks. Thus the tetrad is result of two natural dichotomies[iii].

1. **Denial of Information / Degradation or Destruction (US DoD),** i.e. concealment and camouflage, or stealth; DoI amounts to making the signal sufficiently noise-like, that a receiver cannot discern its presence from that of the noise in the channel.
2. **Deception and Mimicry / Corruption (US DoD),** i.e. the insertion of intentionally misleading information; D&M amounts to mimicking a known signal so well, that a receiver cannot distinguish the phony signal from the real signal.
3. **Disruption and Destruction / Denial [1] (US DoD),** i.e. the production of a dysfunction inside the target system; alternately the outright destruction of the receiver subsystem; D&D amounts to injecting so much noise into the channel, that the receiver cannot demodulate the signal.
4. **SUBversion / Denial [2] (US DoD),** i.e. the modification of the target system to prevent behaviour which benefits the target or to produce self destructive behaviour; SUB amounts to the diversion of the thread of execution within a Turing machine, changing the functional behaviour[iv].

The models for these strategies, and Exploitation, are depicted in Figures 1 and 2.

There is an abundance of contemporary or recent historical examples to illustrate the four canonical strategies, especially in the domain of electronic warfare and electronic attack. Detailed discussions of these can be found in references (Fitts, 1980), (Schlesinger, 1979), (Knott, 1985), (Knott, 1993) and (Ball, 1985).

2. INFORMATION WARFARE IN NATURE

A question of great interest is that of how general models of Information Warfare based upon Shannon and hypergame theory actually are, and whether examples of these models can be found in other domains, especially those which predate human conflict.

Each of the four canonical Information Warfare strategies are methods of using information in order to achieve an aim yet minimise the expenditure of resources. This is clearly evident in typical contemporary military instances of Information Warfare. For instance, jamming an opposing missile system reduces the number of aircraft lost in an engagement, on average, thereby minimising the expenditure of material and personnel.

Energy, material, time and safety are all scarce resources that are required by biological entities. The need for each of these can be reduced by structural changes in a biological entity which effectively encode more efficient methods of achieving reproduction. Biological entities which acquire this information become more numerous. Indeed, the body of each biological entity is a record of information about the environment which evolution has succeeded in encoding in the body.

Broadly, to exploit information to effect a change in the surrounding environment that information must be applied against an entity which is unstable or metastable. Consequently, a small amount of energy can effect a large change. The most unstable entity in the environment of any biological entity will be other biological entities. These form a resource of enormous potential to an evolving species. A priori we could not expect this resource to be ignored.

Many species have sensors to detect food and predators. If food is fast enough it can run away; but if not, then it can hide, so as not to be seen; it can pretend to be a poisonous insect or spit in the eyes of the predator. These very common behaviours cover the first three of the canonical Information Warfare strategies explicitly. Examples of subversion are also very common, but often require a more subtle examination to detect.

The *New Zealand White Tailed Spider* climbs onto the web of a *Grey House Spider* and plucks the web with its palps to attract the *Grey House Spider*. The victim is then killed and eaten. The *Portia* spiders exhibit similar behaviour[v] :

"Master of camouflage and expert at mimicry, *Portia fimbriata* spider of Australia plays a dangerous game. It hunts other aggressive spiders by strumming their webs to imitate mating behaviors or the actions of distressed prey, or merely to rouse their curiosity." Cited from (Jackson, 1996).

Parasites are in an excellent position to subvert the neural anatomy of the host organism. Some parasites of the class *Trematoda* affect snail physiology and behaviour, *T. leucochloridium* makes the snail bask in sunlight, so it is eaten by a bird which propagates the parasite. While this is chemically induced control, the primary effect of its chemical is not that of a poison, but of a behavioural modifier. Another trematode species induces ants to run up grass stems so as to be eaten by sheep, which further propagate the parasite.

The rabies virus causes infected carnivores to become aggressive, and bite other animals, thus propagating the virus.

One ant species can induce victim ants to kill their own queen, and elicit aggressive supporting behaviour from victim worker ants to do so. Slaver ants seduce pupae of victim ant species into the belief that they are part of the slaver species' colony, refer (Dawkins, 1982).

But demonstrating empirically the generality of any model in nature can be a difficult task, especially when dealing with biological systems of great diversity and age. An exhaustive analysis of every single species to catalogue which Information Warfare strategies they may employ to aid in survival is a task of such magnitude as to be wholly impractical.

To demonstrate that Information Warfare is an evolved survival aid in the biological domain, it is necessary to find a set of examples which meet the following criteria:

1. The species employs one or more than one of the four canonical strategies to aid in its survival.
2. Multiple species which are not closely related, and preferably exist in diverse environments, employ the same subset of the four canonical strategies to aid in their survival.
3. Closely related species exist to the examples found, which do not employ any of the four canonical strategies to aid in their survival.

The essential argument espoused by evolutionary theorists is that specific features in a species which improve its probability of individual survival and reproduction will be propagated, at the expense of features which impair the probability of individual survival and reproduction, refer (Dawkins, 1996) and (Wills, 1989).

A set of species which share the common attribute of using a set of the four canonical Information Warfare strategies, yet are not closely related biologically, could only have developed the use of this set of strategies under evolutionary survival pressure, as the absence of a near common ancestor denies the immediate inheritance of the trait[vi] .

A number of examples will be explored, mostly selected from insects, arachnids, molluscs and fishes, since these groups are exceptionally diverse but also relatively old in evolutionary terms.

2.1 Denial of Information in Nature

This strategy is perhaps the most commonly found in nature, and is used both by predators and prey alike, in the form of camouflage. Camouflage is an exceptionally powerful technique if well implemented insofar as it yields no information whatsoever to an opponent in an engagement. Several examples will be explored to provide convincing breadth, refer (Preston-Mafham, 2000) and (Randall, 1997).

Orthoptera - Grasshoppers, Crickets and Katydids: this order is large with $\approx$ 20,000 species cited. A large proportion of these are exceptionally well camouflaged in colour, texture and frequently also shaped to blend against their habitat and evade predators. Many species have camouflage which is uniquely adapted to hide against dead leaves, bare dirt, grasses, stones and green foliage.

Mantodea - Mantids: these predators lack agility and hunt primarily by ambush, therefore the effectiveness of their camouflage will reflect directly in how many meals they have. Species which have remarkably effective camouflage are the Brazilian *Acanthrops falcataria* which hides as a dead leaf, the Indian *Humbertiella ceylonica* which hides against tree bark **-** a very wide range of mantids hide against green foliage.

Phasmatodea - Stick and Leaf Insects: these slow moving herbivores have evolved camouflage in their shape, colour, texture and movement, to hide from predators by resembling dead or live foliage.

Arachneidae - Spiders: from the perspective of camouflage, the most interesting spiders are the tree and ground dwelling ambush predators, such as the tarantulas in the Americas, huntsmen in Australia and baboon spiders of Africa.

Orectolobidae - Wobbegong Sharks: these sluggish bottom dwelling members of the shark family employ very effective camouflage to evade larger predators, and to facilitate predation upon smaller species.

Soleidae, Pleuronectidae and Bothidae - Sole and Flounders: these flatfish hide against the bottom and have diverse but well developed dorsal surface camouflage to evade predators.

Serranidae - Rockcods and Groupers: many members of this reef dwelling family of predators have exceptionally well developed camouflage.

The case for DoI in nature, in the form of camouflage is virtually irrefutable given the enormous number of examples. It is of interest that some of the best developed instances are found in predator and prey species alike which lack agility, therefore Information Warfare is a substitute survival tool[vii] .

2.2 Deception and Mimicry in Nature

Deception and mimicry, where a species evolves the appearance of another to aid its survival, is not as common as camouflage but nevertheless many good examples can be found, refer (Preston-Mafham, 2000) and (Randall, 1997):

Lissocarta vespiformis: this Peruvian leaf hopper bug mimics the appearance of the *Polybia catillifex* wasp, and exists in two known forms.

Sphrodolestes and Hiranetis braconoformis assassin bugs: a number of South American assassin bugs mimic a range of wasp species, the *Hiranetis braconoformis* producing a remarkably good imitation of the *Monogonogastra* braconid wasp.

Scaphura katydids: these relatives of grasshoppers not only appear like wasps in colouration and shape, but also mimic the movements of a wasp when disturbed.

Arctiid moths: these Peruvian daylight moths have transparent wings and black and yellow colouration resembling a wasp.

Riptortus bug: nymphs of this Australian species closely resemble the common green tree ant *Oecophylla smaragdina*, both in colouration and shape.

Aspidontus taeniatus: this member of the *blenny* family mimics the *cleaner wrasse* in order to approach larger fish and bite parts off the fins, while avoiding predation.

Paraluteris prionurus: this small leatherjacket mimics the shape and colour patterns of the poisonous *Canthigaster valentini* pufferfish.

Cheilodipterus parazonatus: this small candinalfish mimics the venomous *sabre-toothed blenny* to deter predators.

Antennariidae - Angler Fish: this family of fish has evolved an elongated first dorsal spine which is used to lure prey close enough to be eaten. While these species use their lure to elicit a predatory behavioural response from their prey, they also employ DoI in the form of camouflage to support the subversion strategy.

Photuris - Fireflies: north American fireflies of the *Photuris* species employ modulation of their light flashes to attract mates. However, females of a number of *Photuris* species are also known to alter their modulations to mimic closely related species, in order to lure males of these species as prey. Stous notes that "*Photuris versicolor* is known to prey on eleven species of firefly, and twelve other *Photuris* species prey on at least two, or more, species. On the flip side, one prey species in Florida has 6 predators, therefore there is overlap between *Photuris* species in their flashing [behaviour]". The behaviours include luring other species close enough to perform an aerial attack, or hovering in the vicinity of a female which is signalling to ambush arriving males. Refer (Stous, 1997).

The example of the *Photuris* firefly is exceptionally interesting from the perspective of Information Warfare since it involves the use of a modulated light signal as a homing beacon in

mating behaviour. The *Photuris* which lures other species is performing in effect the technique known as *meaconing*, refer (Schlesinger, 1979). The related variants of these behaviours reflect many established electronic warfare techniques such as manipulation of Identification Friend Foe signals. Stous describes the result as an ‘evolutionary arms race’ as different behaviours and light modulation codes are evolved to defeat predatory behaviour, or in turn defeat ‘countermeasures’ to predatory behaviour.
While instances of mimicry are much less frequent than camouflage, they demonstrate a convincing case insofar as multiple mimic species from very diverse and large families may mimic one family, such as wasps in South America.

2.3 Disruption and Destruction in Nature

Disruption and destruction is centred upon techniques which disable or impair the basic function of an opponent’s sensory apparatus or ‘receiver’. Noxious fluid discharges or aerosols which can irritate another specie’s olfactory or taste sensor or eyes represent good examples.

Stink Bugs: a very wide range of stink bug species exist. When disturbed, these typically release a foul smelling aerosol which impairs the ability of a predator to precisely locate the bug by smell.

Blattodea - Cockroaches: a number of cockroach species will spray a noxious fluid when disturbed, again to impair the olfactory sense of the victim.

Anisomorpha buprestoides: this North American walkingstick insect will spray an irritant fluid into the eyes of a predator if threatened.

Sepioidea - Cuttlefish: close relatives of squid, will blind predators by discharging a cloud of ink.

D&D as a survival aid seems less common than DoI and D&M. This is arguably because of the difficulty in accurate targeting of the discharge, and the limited amount of defensive agent which can be stored. Once the agent is discharged, rapid escape or hiding is the only remaining defence.

2.4 Subversion in Nature

Subversion is a technique which is used in nature, albeit not as frequently as the other three canonical strategies. As it is a more complex strategy to execute, this might explain why it is less common than simpler strategies. The following examples are cited in (Dawkins, 1982).

Cuculus canorus: The cuckoos subvert the nervous system of the host parent, in order to addict it to the feeding of the cuckoo[viii] .

Bothriomyrmex regicidus and decapitans: Queens of these ‘cuckoo’ ant species will invade another ant colony, kill the queen and seduce the colony worker ants into rearing the usurper’s brood.

Monomorium sanschii: Queens of this ‘cuckoo’ ant species will will invade another ant colony and emit a chemical which alters the behaviour of the victim ants. These will attack and kill their own queen, adopting the invader as their new queen. If we view the ant colony collectively as part of a survival machine for the queen (a valid, but not uniquely so, perspective) then this is a major example of functional subversion of the target system.

Molothrus ater: The brown-headed cowbird can elicit preening behaviour from bird species which do not typically preen. Again, this is an example of subversion, as the bird wastes time preening its attacker (while superficially benign, this is an attack, since the victim bird species is wasting time and energy doing the preening), a behaviour that is not a part of its established repertoire.

Hymenoepimecis: The parasitic *Hymenoepimecis* wasp attacks the *Plesiometa Argyra* spider. The victim is stung into temporary paralysis. The *Hymenoepimecis* then lays an egg on the spider's abdomen; the egg hatches into a larva that grows by sucking the spider's internal fluids. The larva induces the spider to build a cocoon web, and then moults, after which it kills and eats the spider. Finally the *Hymenoepimecis* larva spins its pupal cocoon hanging by a line from the cocoon web. This subversion is chemical in nature, refer (Eberhard, 2000).

While subversion is demonstrably the most complex of the four canonical strategies to execute, it is also by far the most devastating to the victim, as it directs the victim's internal resources to a self destructive end in both senses of the word. A pre-requisite for a subversion attack must be some vulnerability in the basic algorithm which drives the victim system's behaviour - exploitation of this vulnerability is central to success in a subversion attack[ix].

3. CONCLUSIONS

Nature is clearly abundant in instances where one or more of the four canonical strategies of Information Warfare have evolved as survival aids. Against the three test criteria we defined to establish that these strategies are indeed evolved features of species, even a cursory browsing of several respectable texts has yielded a large package of examples.

It takes little effort to conclude that the hypothesis of 'Information Warfare being an evolved survival mechanism in nature' can be proved by a large number of examples.

While instances of the four canonical strategies of Information Warfare in nature may be of little practical relevance to the development of Information Warfare as a modern discipline, they do substantiate the position that Information Warfare is a very fundamental paradigm, which has been part of nature for hundreds of millions of years.

The existence of Information Warfare as a demonstrable component of the evolutionary arms race between species could be of particular interest to researchers in the domain of evolutionary psychology, refer (Badcock, 1995) and (Miller, 2000), as it could provide some interesting insights into human evolution. That is an area for future research.

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[i] Cited in (Borden, 1999), refer (Widnall, 1997).

[ii] Refer Kopp C, 'Shannon, Hypergames and Information Warfare', unpublished draft paper, July, 2002.

[iii] In the biological sense a dichotomy is a division into two classes. Two independent dichotomies produce four classes, the tetrad. Each dichotomy is a choice between degrading the correct operation, or enhancing the incorrect, a fairly natural dichotomy. However, this is not a *logical dichotomy* as the one strategy does not logically exclude the other.

[iv] The US DoD model includes Exploitation as a fourth 'Attack Measure', Exploitation defined as gathering an adversary's flow of information to facilitate friendly information generation. Exploitation amounts to attaching a receiver in parallel with the opponent's receiver. Since it does not in itself produce an immediate causal effect in the function of the target channel, it cannot be classified as an offensive Information Warfare strategy in the sense of the four defined strategies. Rather, it is an information gathering 'technique', albeit one which may facilitate the application of an offensive Information Warfare strategy.

[v] The authors are indebted to Phil Sirvid of the Museum of New Zealand in Wellington, and Grace Hall of Land Care - Research in Auckland, for their helpful advice on these species.

[vi] Dawkins develops an analogous argument in (Dawkins, 1996), p91, in relation to trunks in diverse species, where similar evolutionary pressures shaped the evolution of similar features.

[vii] Dawkins in (Dawkins, 1996), p87, discusses the dark and light camouflaged *Biston betularia* moth variants. The darker variants thrived in areas with heavy industrial pollution, the lighter variants in unpolluted areas. Within the mixed population of dark and light camouflaged moths, those with the least well adapted camouflage for their habitat were most frequently taken by predators thus resulting in a predominance of dark moths in industrialised areas and light moths in rural areas.

[viii] Dawkins argues that the subversion performed by the cuckoos might actually be deception and mimicry insofar as the cuckoo has elicited a functionally normal albeit misdirected behavioural response from the victim, refer p70 in (Dawkins, 1982). The distinction between some forms of subversion and deceptive behaviour can often be subtle.

[ix] It is worth noting that biological instances of subversion frequently rely upon a chemical messaging mechanism to subvert the 'wetware' of the victim species. Chemical messaging which effects state changes in the victim system is an idiosyncratic aspect of the use of biological computational machinery.