

## Chapter-2

# SIGN STIMULI & STIMULUS FILTERING

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### SIGN STIMULUS

In ethology, a fixed action pattern (FAP), or modal action pattern, is an instinctive Behavioural sequence that is indivisible and runs to completion. Fixed action patterns are invariant and are produced by a neural network known as the innate releasing mechanism in response to an external sensory stimulus known as a **sign stimulus** or **releaser**. It was Konrad Lorenz who first realized that specific stimuli (which he called as the key stimulus) was needed to release the FAP. He said that the stimulus acts as a key which unlocks and opens a particular fixed action pattern.

A sign stimulus is a part of a *stimulus configuration*; it is external to the animal, and relevant to a particular response. Quite frequently one finds animals responding to only one special part of the array of stimuli presented to them. It means that an animal responding in a non-reflex fashion utilizes only restricted aspects of the environment apparently ignoring the others i.e. it responds to only a part of the potential information contained in the stimulus situation. This relevant part is called the *sign stimulus*. It is the essential feature of a stimulus, which is necessary to elicit a response. In order to discover which part of the stimulus configuration has got the sign stimulus value, that part must be experimentally altered or even eliminated. In doing so however other parts may be altered as well and in each case it must be determined as to what extent a sign stimulus depends upon the total stimulus configuration.

### ESSENTIAL FEATURES OF SIGN STIMULI

**A. A particular cue :** *In sign stimuli, a particular cue or a specific sign is of critical importance and is responsible for releasing a Behaviour.*

**Examples :**

1. The males of three-spined stickleback (*Gasterosleus aleatus*), a small freshwater fish, during the breeding season develop a red coloration on the underside of their bodies and become highly territorial. They select a site, form a tubular nest and defend it actively by fighting and chasing an intruder male. Niko Tinbergen in 1952 performed some classical experiments on the stickleback wherein he constructed some models to study the specificity of the sign stimuli (Fig 4).

- Model A was very realistic but did not have a red colored underside.
- Model B and C were of odd shapes but had a red bellies

When presented to the stickleback fish, models with the red underside alone acted as sign stimulus for releasing attack Behaviour in other male sticklebacks. It was therefore concluded that the red belly is of critical specific sign stimulus value for releasing territorial defense in male sticklebacks.

2. The chicks of the songbirds which are born blind and helpless, respond to jerks in their nests. In nature when the parents arrive in the nest, it creates a movement which acts as sign stimuli for the chicks so that they turn their heads in the direction of the movement and open their mouths. The coloration on the inside of the mouth of the chicks or just the sight of the gape in turn acts as a sign stimulus for the parents to regurgitate food.

3. Turkey hens breeding for the first time will accept as chicks any object that makes a cheeping call. On the other hand they ignore visual stimuli in this situation and deaf turkey hens kill most of their chicks because they never receive the auditory sign stimulus for parental Behaviour. (Schleidt 1960).

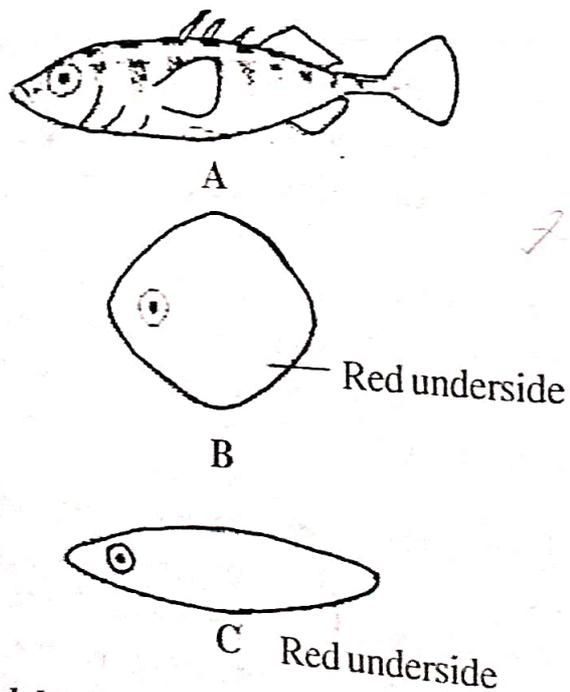


Fig 4. Models of male stickleback used by Tinbergen

**B. Configurational relationship:** A common property of many sign stimuli is their spatial configurational relationship i.e. the sign stimuli must be presented in the right perspective to elicit a response

**Example:**

In the case of the stickleback fish it has been found that the red coloration on the models must always be on the underside in order to elicit a response. A model of a male with a red back is about as ineffective as a male without any color.

**C. Internal state of organism:** When one part of the total situation is found not to be a sign stimulus for a particular response, it might well have sign stimulus value for another response. What stimulus the organism will respond to depends upon the internal state of the organism

**Example :**

The herring gull (*Larus argentatus*) robs the eggs of other gulls nesting in the colony. An egg must be normally shaped and undamaged to act as a releaser. During incubation, however, responses to the egg are released by quite different stimulus properties.

- For a herring gull approaching its own nest, factors such as color, speckling, and size of the egg have sign stimulus value while shape does not: the egg may have the shape of a cylinder, a ball, or a cone.
- Once the gull settles on its eggs, however, shape becomes a crucial feature. If the eggs do not have rounded smooth edges, the bird will frequently rise and resettle in a disturbed manner.

Thus, for three different acts, three sets of sign stimuli of one and the same stimulus object are responded to. The selection of different sign stimuli by a gull in each of the three cases permits one to reject the idea that the gull is unable to perceive the irrelevant cues in each case. Rather, it has to be assumed that the internal state of the bird determines which stimuli the bird will respond to in each context.

**D. Effect of stimulus strength:** Many alterations in sign stimuli evoke a weaker or stronger response in the animal responsive to them. In stimulus analysis, therefore, it is necessary to make sure there is a reproducible stimulus property.

**Example :**

Territorial pied flycatchers (*Ficedula hypoleuca*) tend to mob a male red-backed shrike (*Lanius collurio*), a potential predator. An indispensable sign stimulus eliciting the mobbing response (calls/minute) is the black eye bar of the shrike. Dummy experiments have shown that when the shade of the bar is varied, so as to decrease the contrast of the bar against the light grey head, the mobbing response decreases. How precisely the birds attend to the nature of the bar is

indicated by the two weakest stimulus values of the series (Fig. 5) the slightest contrast that scarcely perceivable to our eye still elicits mobbing although it is not significantly different response evoked by a bar less male.

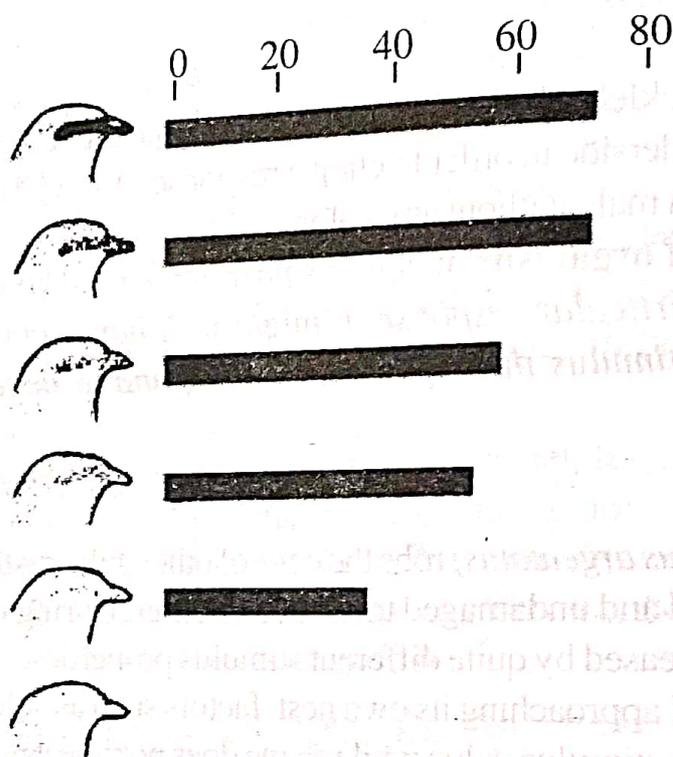


Fig 5. Showing the strength of response to sign stimulus by flycatchers

**D. Heterogeneous summation :** Sometimes the sign stimuli is not just one but a combination of many. Moreover in such cases the effectiveness of a stimulus pattern in releasing a Behaviour increases with the number and the intensity of the stimulus components involved. Furthermore these components involved may replace each other functionally. This has popularly come to be known as the rule of heterogeneous summation.

**Examples:**

1. Fighting Behaviour in the males of the African cichlid fish *Haplochromis burtoni* is elicited by five stimuli
  - Silvery blueness of the body
  - Dark margins
  - Broadness of the animal
  - Parallel orientation to the opponent
  - Tail beating

It was found that any one of these stimuli was capable of eliciting hostile Behaviour and any

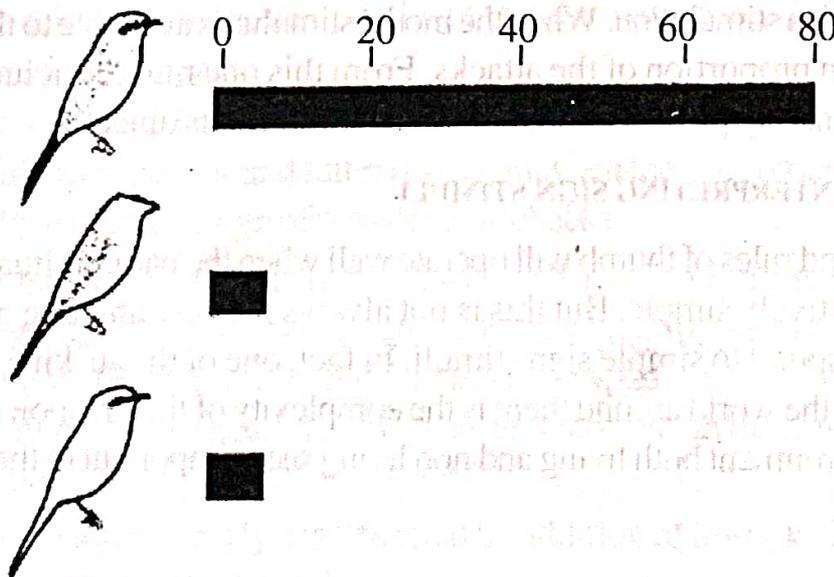
two stimuli would produce twice the effect of one. Therefore in such instances, the response of the releasers appears to be additive.

2. Egg-retrieving Behaviour in the herring gull is affected by a number of visual properties of an egg on the rim of the nest. Size, speckling, and background coloration (green being more effective than brown) have been shown to be important, and each of these components adds algebraically to the effect of the others. With constant egg background coloration, the omission of speckling could be compensated for by a constant increase in size for all values of size tested. The effects of speckling and size are thus additively superimposed, and either can be substituted for the other to produce the same total stimulus value.

**E. Stimulus interaction:** *Stimulus pattern components in cases of multiple sign stimuli do not always follow the rule of heterogeneous summation. In most other cases stimuli depend on the associated presence of others; that is, they show stimulus interaction. In the extreme, this may lead to the total breakdown of recognition of a pattern, even if only one characteristic of the whole is missing.*

**Example:**

Territorial pied flycatchers mob a male red-backed shrike model more strongly than any other shrike model used. A model possessing only the black eye bar and another showing the rest of the whole color pattern of the male shrike are virtually ineffective. By adding up their stimulus values one obtains only a minor fraction of the response to the whole pattern (Fig 6). Apparently, both pattern components depend on each other in their effectiveness i.e. they do not follow any pure algebraic summation paradigm as referred to above.



**Fig 6. Showing stimulus values of three models of red backed shrike**

**F. Interaction with the background:** Components of a pattern in cases of multiple sign stimuli may also interact with the background of a stimulus object and not only with each other.

**Example:**

The young of the cichlid fish, *Hemihaplochromis multicolor*, are cared for by the female parent, which they follow about. A substitute for the mother that is able to elicit the following approach by the young must be somewhat darker than the background. This flexibility of the response correlates well with the nature of the physiological color change of the adult fish. It is always somewhat darker than its background, and thereby always offers to its brood an optimum stimulus situation.

**G. Motivation properties of sign stimuli:** Sign stimuli not only have a releasing function. In addition, they direct responses in space, and they often change the readiness of the recipient to respond in a particular way.

**Example:**

This aspect can be illustrated by the fighting Behaviour of *Haplochromis burtoni*. An experimental male fish is continuously allowed to observe temporarily blinded juveniles which it attacks from time to time. A brief exposure of the male to a rather effective model of a male (without the attacks suppressing orange patch) raises its readiness to attack the young test fish. The stimulus model cannot be bitten because it is presented behind a glass plate. Thereafter, the raised level of responsiveness abates at a much slower rate. While the less effective blind test fish apparently elicit occasional attacks, the much more effective stimulus of the male model motivates the territorial fish to attack more often than before. The difference between both effects of a stimulus is most clearly seen in that attack readiness increases for a relatively long period compared to the period of sudden stimulation. When the model stimulus is available to the experimental fish, it receives a certain proportion of the attacks. From this one must conclude that eliciting and motivating properties are present in one and the same stimulus object.

**PRECAUTIONS IN INTERPRETING SIGN STIMULI**

Sign stimuli and rules of thumb will operate well when the natural situation and the decision to be made are relatively simple. But this is not always the case and one must not assume that animals always respond to simple sign stimuli. In fact, one of the striking features of the ways animals respond to the world around them is the complexity of their response and many different features of the environment both living and non living seem important to them.

**Examples:**

1. The bee-killing digger wasp (*Philtinihus triangulum*) and, under certain circumstances

honey-bees (*Apis mellifera*), make use of landmarks to relocate their burrows or their hives, respectively.

2. Jackdaws (*Corvus monedula*) and tits (Paridae) mob when a conspecific is threatened by the approach of a mammalian predator.

3. Still more perplexing Behaviour can be observed in hamadryad baboons (*Papio hamadryas*). A subordinate group member usually gives way to superior members, but if the dominant male is at its back, the subordinate animal will occasionally threaten one of the other more dominant members without eliciting their attack. (The dominant male would immediately interfere if the subordinate animal were attacked.) Hence, the subordinate must, in some way, be certain that it takes no risk when performing the 'safe' threat.

### SUPERNORMAL STIMULI

A common method of investigating sign stimuli is to present animals with dummies or models of a natural situation and then to change these in certain ways to see which are most important to the animals. A very curious phenomenon has emerged from a number of these studies: it is often possible to produce a model that produces a greater response from an animal than the natural object does.

#### Examples :

Examples of such 'supernormal' stimuli are found in all sorts of animals, but some of the oddest have come from the incubation Behaviour of birds.

1. Tests have been made with the herring gull, the graylag goose and the oystercatcher and in all three, the larger an egg is, within broad limits, the more it stimulates incubation.

2. Male sticklebacks preferentially court large females with distended abdomens, which indicate that they have a lot of eggs.

3. Rowland (1989) showed that, when presented with two dummy females, a male would first direct his courtship to the larger and fatter one, even when the 'fat' female had an abdomen distended far beyond the normal range of female sticklebacks.

4. Herring gull chicks will peck at all models of the parent's bill from which they are normally fed with regurgitated fish (Tinbergen and al Perdeck 1950). However, a long thin red knitting of needle is more effective at eliciting the pecking response from a newly hatched chick than a more realistic model with a head, yellow beak and red spat on the lower mandible that a real adult herring gull has.

5. Human lips are made strikingly supernormal by addition of lipstick. They tend to stimulate the eyes of the males more than normal lips

### Why are natural stimuli not supernormal?

It is also easy to understand why the natural stimuli have not themselves evolved towards the supernormal condition. As it is, natural selection can rarely lead to perfection; animals settle for the best compromise. Female fritillaries would attract more males if they beat their wings faster, but their wings are also used for flying and there are severe mechanical limitations on the speed with which they can be moved. Similarly, an adult herring gull's bill would probably be highly inefficient in all but attracting the pecks of its chicks if it were as long and narrow as the supernormal model. There will also be a limit on how many eggs a female stickleback can produce.

## STIMULUS FILTERING

Sense organs of an animal in general are designed to pick up large amounts of information about an animal's environment. Sensory neurons however have modalities and receptive fields that are strongly biased in favor of gathering information that is Behaviourally significant for that species. Higher-order neurons in a sensory system cope with all varied information collected by sensory organs by discarding much of it and keeping only the most significant aspects. These neurons act essentially as filters, and transmit only certain aspects of the signal they receive. A consequence of this is that much of the information present at the level of the sensory receptors is thrown away.

*Stimulus filtering or sensory filtering* can thus be defined as "The process of separating useful sensory information from the many thousands of stimuli present in the external environment, so that only potentially useful information is sent to the brain". Through the process of stimulus filtering the nervous system appears to have developed the capability to perceive and distinguish between minute differences in stimuli, which allow the animal to only react to significant impetus. This enables the animal to conserve energy as it is not responding to unimportant signals.

Filtering is largely achieved by circuits, in which neurons interact with each other through their synaptic connections. As a result of these interactions, some features of the signal are enhanced and others are discarded at each level in a sensory system. This progressive refinement of the sensory signal begins at the very first synapse, between a sensory receptor and a second-order neuron. Generally, lower-order neurons respond to fairly simple characteristics of stimuli, such as changes in brightness. Higher-order neurons, on the other hand, often respond to particular patterns of stimuli in which information coming from particular groups of sensory receptors is combined together.

## EXAMPLES OF STIMULUS FILTERING

1. The calls of male green tree frogs have two peaks of sound energy, a low one at 900 Hz and a high one at about 3000 Hz (Gerhardt 1974). The ears of the females are tuned to pick up these two frequencies in particular: in the female's auditory system, the so-called 'amphibian papilla' is most sensitive to frequencies between 200 and 1200 Hz while the 'basilar papilla' responds best to sounds of about 3000 Hz (Capranica and Moffat 1975). Narins and Capranica (1976) showed a remarkable sex difference in the hearing of a related species of tree frog, which accounts for the fact that males and females respond to different sign stimuli in the call of the male - a double 'co-qui' leading to stimulus filtering. By playing back tape recordings of the males call to the frogs, Narins and Capranica were able to show that males (who attack other males that approach them) respond only to the 'co' note, and females only to the 'qui'. Neuro-physiological recordings made it clear that each sex heard only the note of relevance to itself because the neurons of the inner ear were tuned differently for males and females.

2. Another example comes from the study of moth's auditory system which helps it to escape from bat's echolocation. Attached to the tympanum in the ear of moth are two auditory receptors: A1 and A2. As intense sound pressure waves sweep over the moth's body they cause the tympanum to vibrate thus deforming these receptor cells. This opens stretch-sensitive channels in the cell membrane and provides the effective stimuli for a moth auditory receptor. These receptors work in the same ways that most neurons do, by responding to the energy contained in selected stimuli and changing the permeability of their cell membranes to positively charged ions. Even though the A1 and A2 receptors work in a similar fashion, there are significant differences between them. The differential sensitivity of the A1 and A2 sensory neurons leads to stimulus filtering of the bat vocalizations

- The A1 receptor is sensitive to low frequencies. Long-distance evasion tactics are engaged when the bat is far away and therefore the A1 sensory neurons fire. It serves as the main bat detector, and as the rate of firing increases the moth turns away from the bat to reduce sonar echo.
- The A2 receptor is sensitive to high frequencies. When the bat is in extremely close range, short-distance evasion tactics are engaged with the use of A2 sensory neurons. The A2 receptor is the emergency back-up system by initiating erratic flight movements as a last-ditch effort to evade capture.

The adaptive value of the physiological mechanisms of two distinct receptors aids in the evasion of capture from bats.

3. Female midshipman fish undergo stimulus filtering when it comes time to mate with a male. Midshipman fish use stimulus filtering when listening to sounds produced by underwater species.

Dominant signals underwater range between 60–120 Hz, which is most normally sensitive to the fish's auditory receptor. However, the female auditory system changes seasonally in response to acoustical stimuli in the songs of male midshipman fish. In the summer when female midshipman fish are reproducing they listen to a male humming song that can be produced at a frequency level of 400 Hz. The summer is the reproducing season for the females so their hearing is more sensitive to the high frequency of the male humming.

### ADVANTAGES OF STIMULUS FILTERING

The proximate causes of stimulus filtering can be many things in and around an animal's environment, but the ultimate cause of this response may be the evolutionary advantage offered by stimulus filtering.

- An animal that saves energy by not responding to unnecessary stimuli may have increased fitness, which means that it would be able to produce more offspring, whereas an animal that does not filter stimuli may have reduced fitness due to depleted energy stores.
- An animal that practices stimulus filtering may also be more likely to respond appropriately to serious threats than an animal that is distracted by unimportant stimuli.

### PRACTICE QUESTIONS :

#### ● Multiple choices

1. A fixed action pattern is
  - a. An instinctive Behaviour
  - b. Released by sign stimulus
  - c. Indivisible
  - d. All of the above
2. When organisms respond to only a special part of the array of stimuli presented to them it relates to
  - a. Sign stimulus
  - b. Stimulus filtering
  - c. Fixed action pattern
  - d. All of the above
3. Which of the following characteristics acts as a sign stimulus for the male stickleback fish?
  - a. Position of the fin
  - b. Beating of the tail
  - c. Red color of abdomen
  - d. None of the above
4. Human lips made strikingly beautiful by applying lipstick is an example of
  - a. Sign stimulus
  - b. Stimulus filtering
  - c. Supernormal stimulus
  - d. None of the above

5. In stimulus filtering
  - a. Some signals are enhanced
  - b. Some stimuli are reduced
  - c. Both a and b
  - d. Neither a nor b
6. The concept of sign stimulus was first given by
  - a. Lorenz
  - b. Wilson
  - c. Tinbergen
  - d. Darwin
7. Fixed action patterns are expressed in response to
  - a. Sign stimulus
  - b. Key stimulus
  - c. Releasers
  - d. All of the above
8. Male green tree frog responds to
  - a. co note
  - b. qi note
  - c. co-qi note
  - d. All of the above
9. In stimulus filtering an organism
  - a. Receives all stimuli but reacts to only part of it
  - b. Receives all stimuli and reacts to all of it
  - c. Receives part of the stimuli but reacts to the whole only
  - d. None of the above
10. Which of the following is true for sign stimulus?
  - a. It must be presented in the right perspective
  - b. It can be single or multiple
  - c. Its alterations produce a stronger or weaker response
  - d. All of the above.

● **Very short answer type**

1. What is FAP?
2. What is meant by stimulus interaction of sign stimuli?
3. Give an example of supernormal stimulus?
4. What sort of stimulus information do higher order neurons respond to?
5. To what sound frequencies is the amphibian papilla of green tree frogs most responsive to?

● **Short answer type :**

1. Enumerate the rule of heterogeneous summation with respect to sign stimuli.
2. Explain how stimulus filtering manifests in organisms.

3. Comment on the statement "What stimulus the organism will respond to depends upon the internal state of the organism".
4. What precautions should one undertake in interpreting sign stimuli?
5. Explain what effects multiple sign stimuli produce on stimulus quality?

• **Long answer type**

1. What is sign stimulus? How do sign stimuli differ from supernormal stimuli? Analyze the effects of stimulus strength and stimulus interaction on sign stimuli.
2. Define stimulus filtering. Explain with suitable examples how stimulus filtering occurs in animals. Comment on the advantages of stimulus filtering.