Cetacean Foraging Skills

Cogs 143 * UCSD

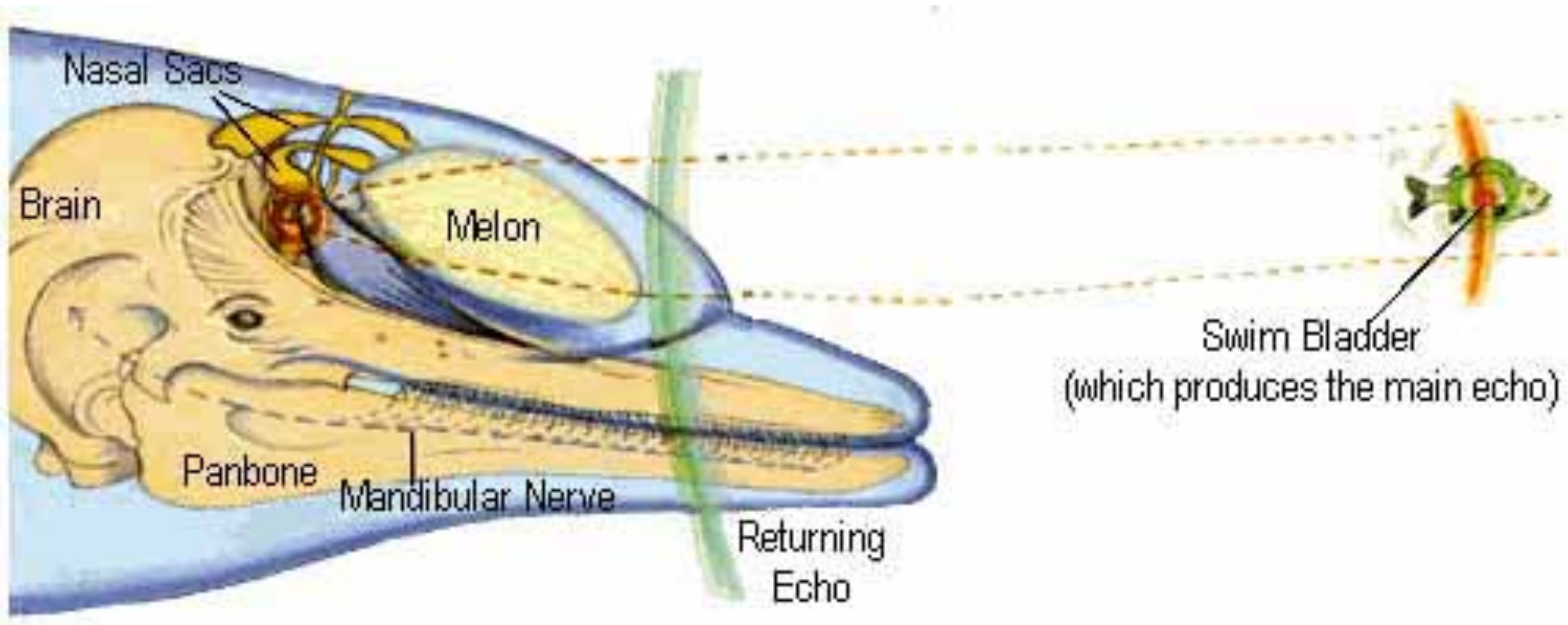
Focus on species that **HUNT** individual prey

Primarily Odontocetes . . .

. . .although,
among the Mysticetes,
also includes
Humpback whales

Unlike most Mysticetes,
Humpbacks eat
FISH

Echolocation



Odontocetes' main strategy for finding, and helping capture, prey

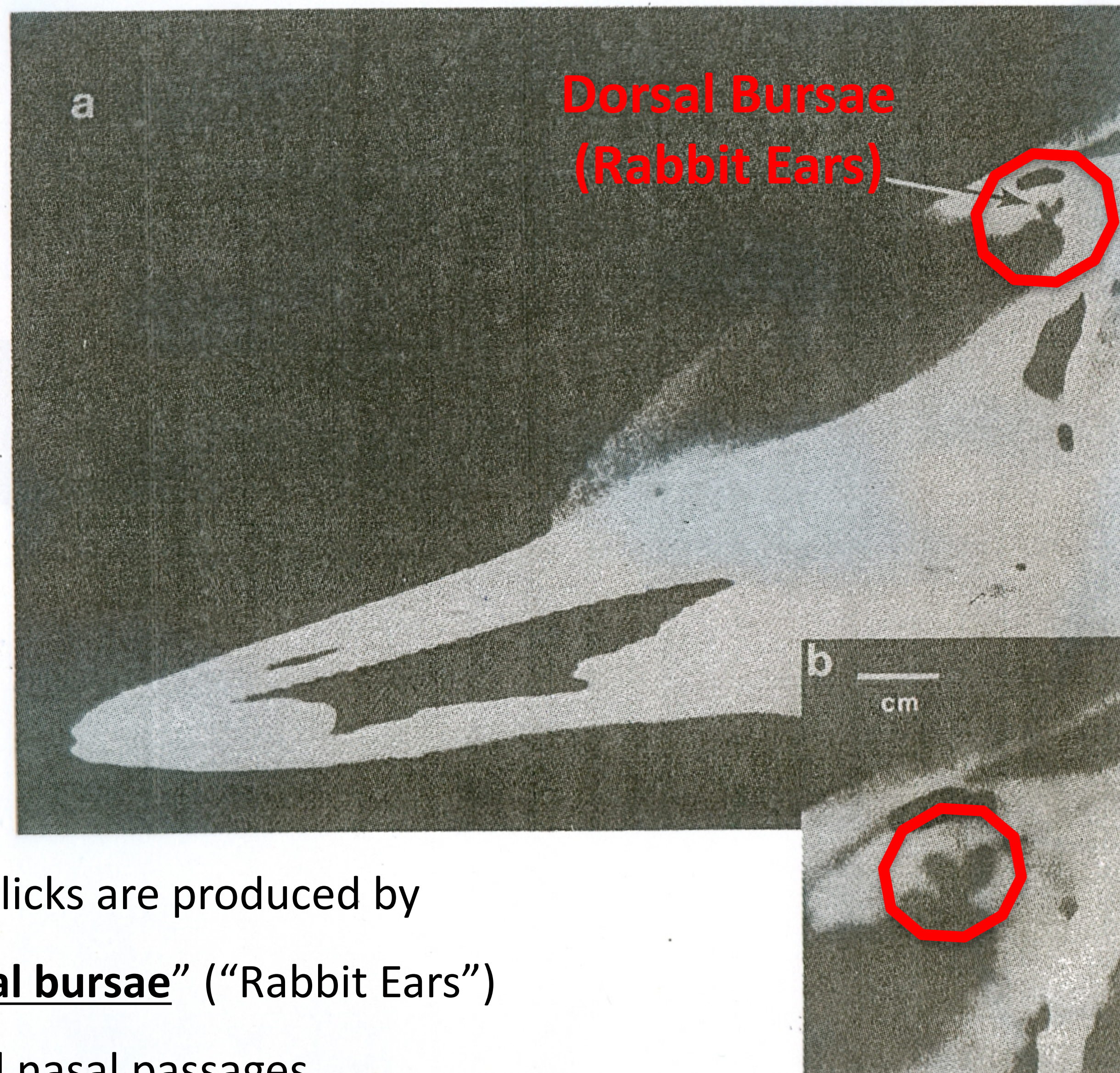


Figure 5.11. (*A*) X-ray projection of the head of a male spinner dolphin. The melon is the dark gray elliptical structure. Near the posterior end of the melon there are two small bulbous projections (arrow) resembling the ears of a rabbit. (*B*) Magnification of the right dorsal bursae. (From Cranford 1988.)

Echolocation clicks are produced by

vibration of "**dorsal bursae**" ("Rabbit Ears")

in dorsal nasal passages

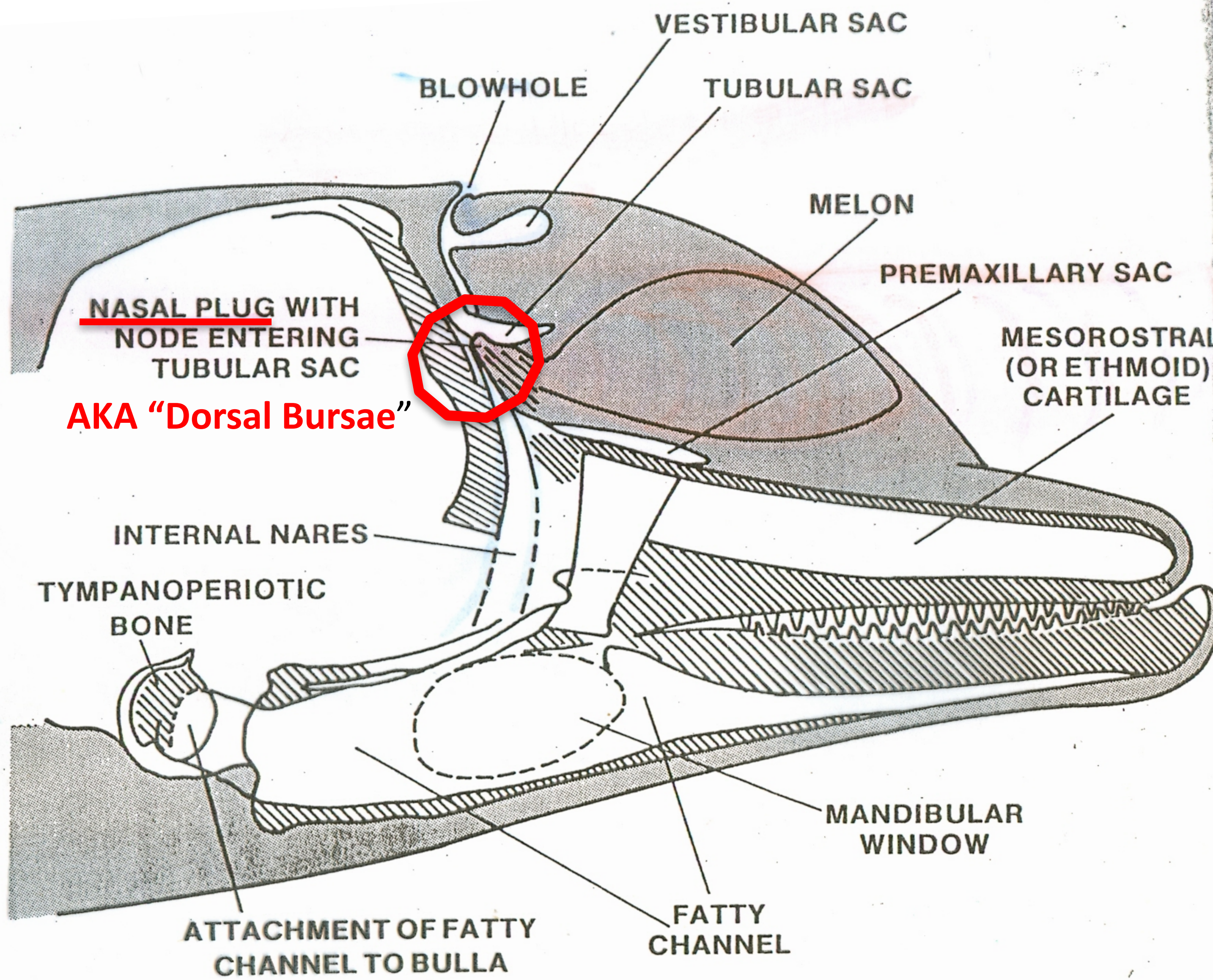
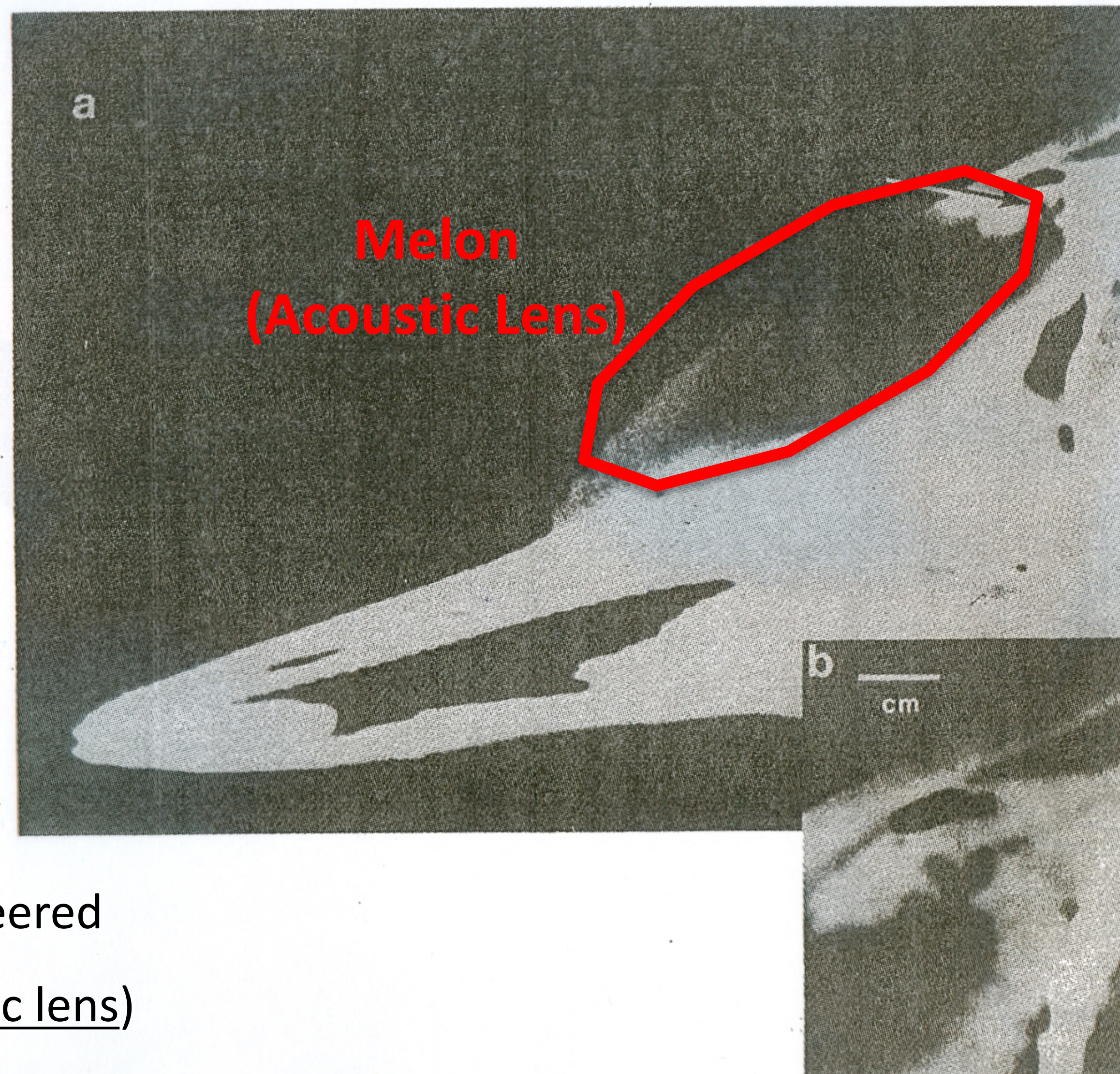


Figure 5.8. Schematic of a dolphin's head showing various structures associated with the theory of sound production in the nasal sac system. (After Norris 1968.)

Asymmetrical Vocal Structures - Right side larger

Dolphins may use
right side
predominantly
for clicking,
altho both sides
can be activated at once.



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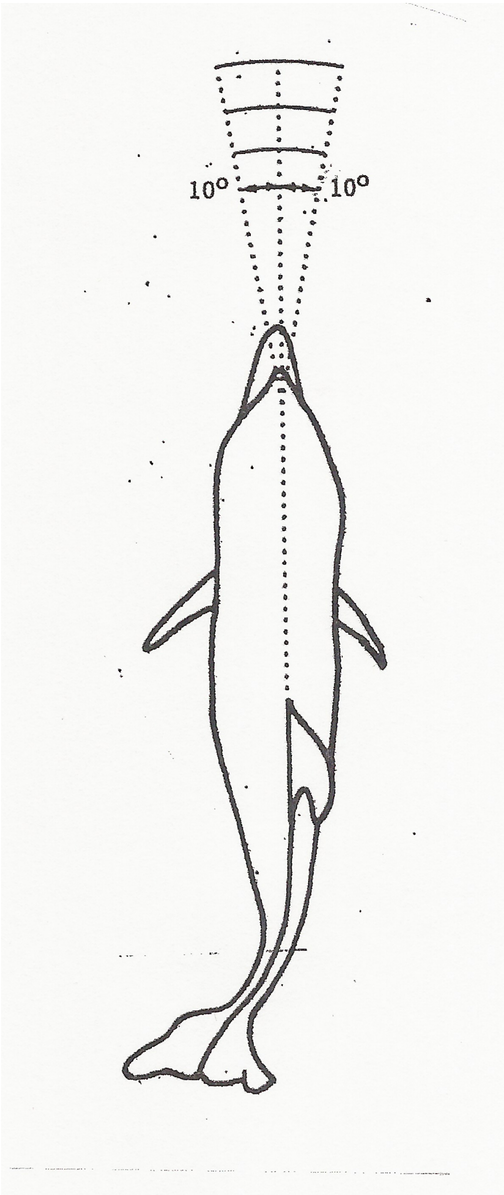
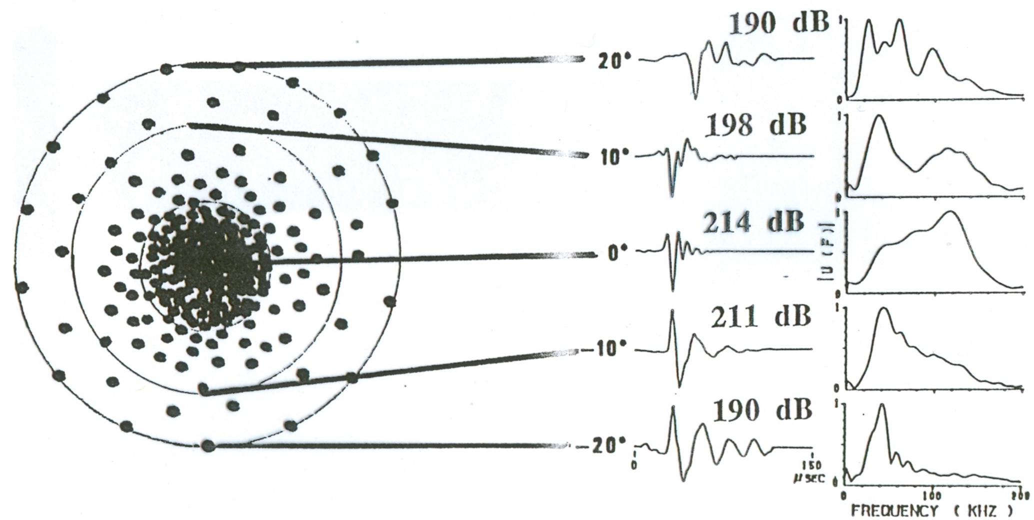
Beam is focused & steered

by fatty **Melon** (acoustic lens)

in forehead, adjacent to bursae



Narrow, focused beam



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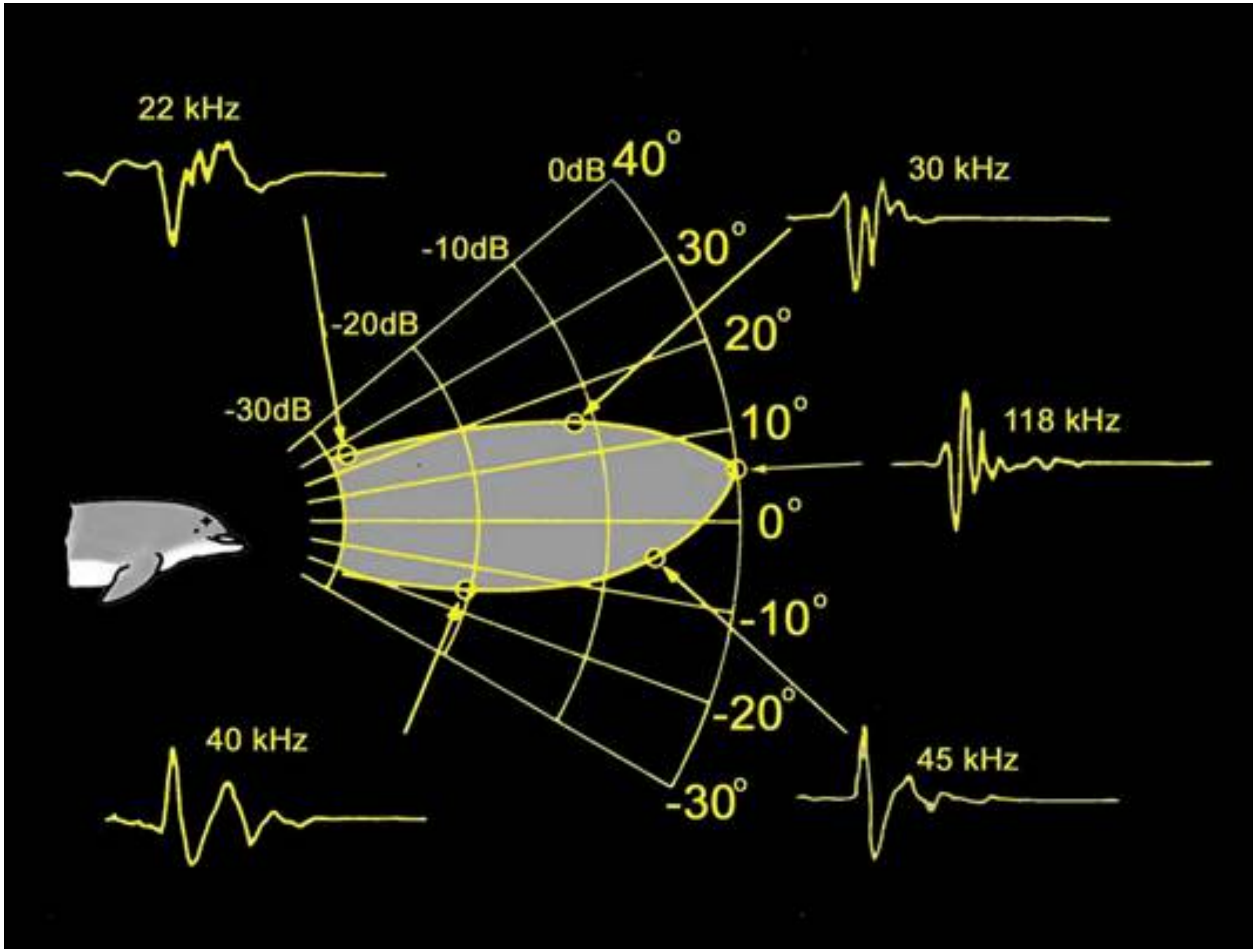
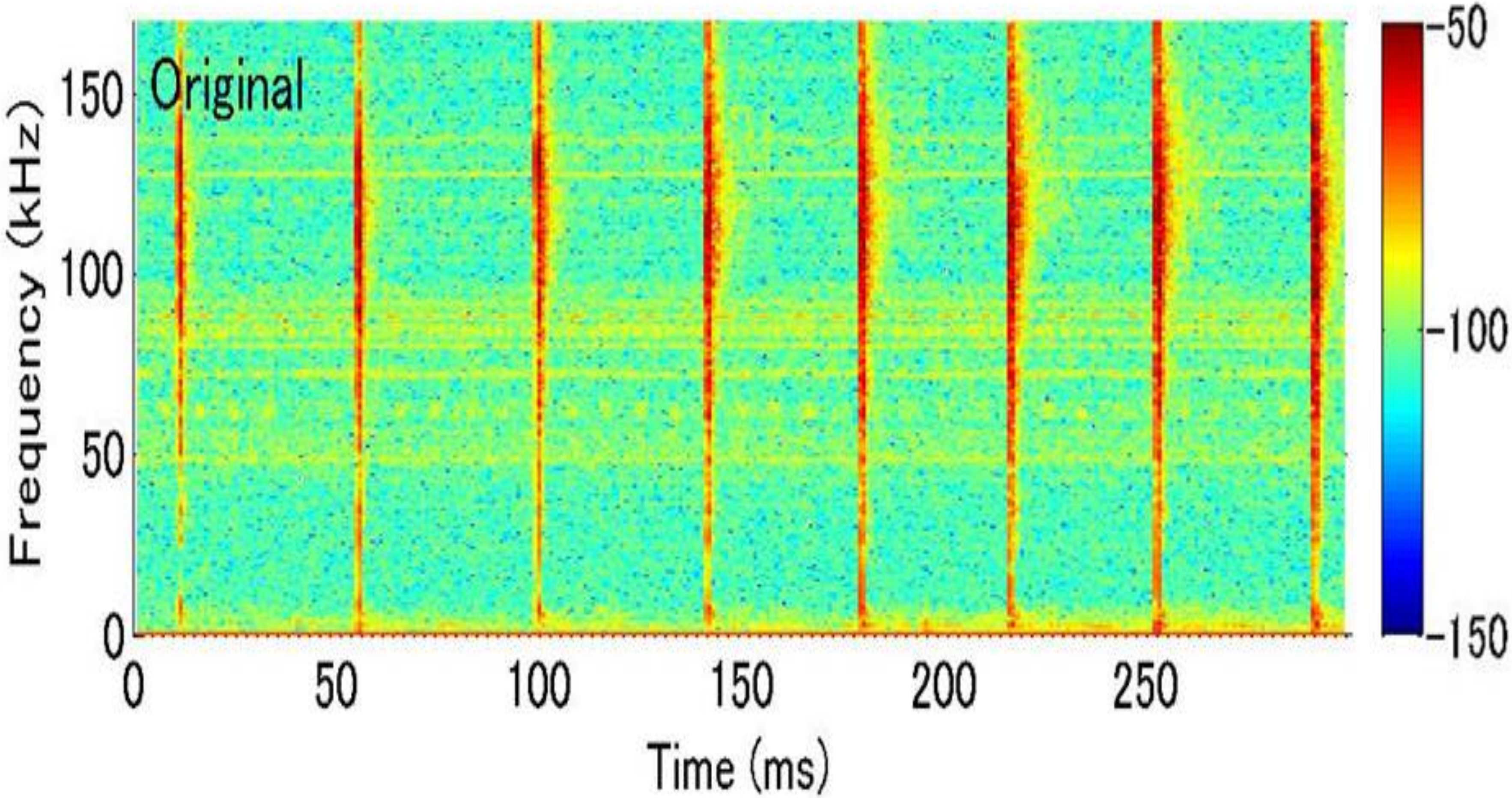


Echolocation "Click Train"



"**Broadband**" = each click includes energy at full range of frequencies (e.g. 0.5-150kHz)

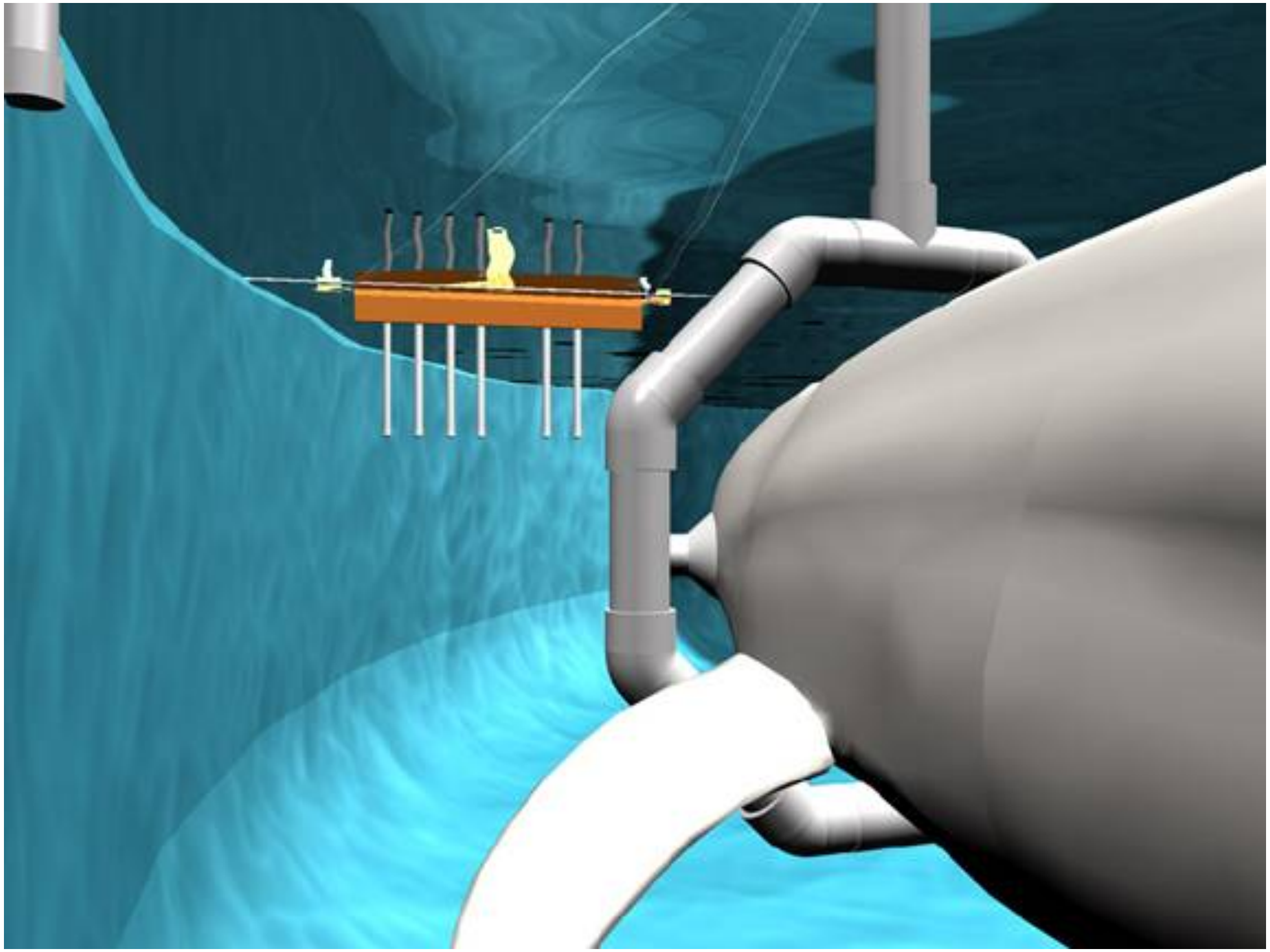
(Human hearing: 0.2-20kHz)

Research on Echolocation

Dolphins trained to wear opaque eye-cups, so must rely on echolocation only.

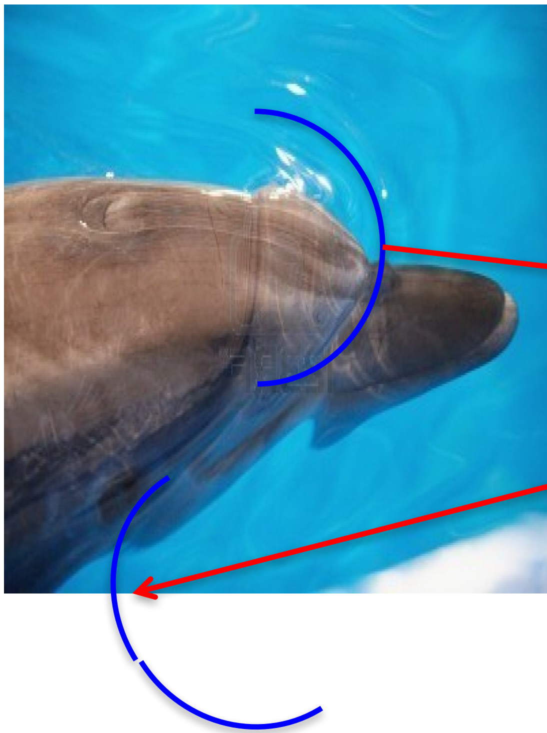
Research on Echolocation

Often positioned in head brace or bite-bar, required to discriminate distant objects



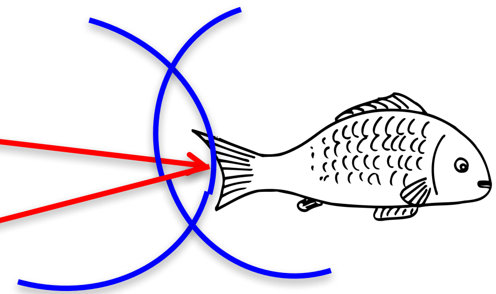
Lag-Time

The time required for one click to travel to and from the Target



(Sound travels 4.5X faster in water than in air:

~1482 m/sec)

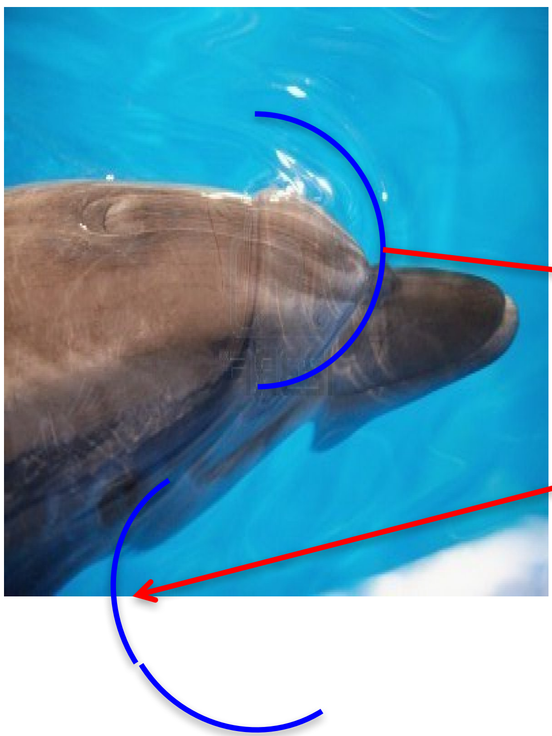


Typical Lag Times:
0.020 to 0.045 seconds
(20-45 msec)

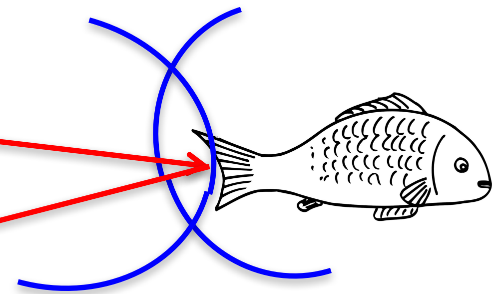
Shortest can be ~ .003
(3000 clicks/sec!)

Lag-Time

The time required for <u>one click</u> to travel to and from the Target



Dolphins will usually delay next click until first echo is received*

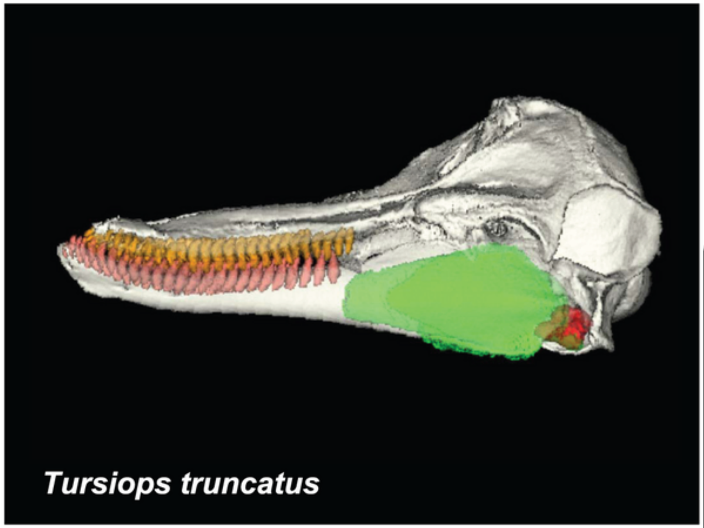


So, click <u>repetition rate</u> can increase as distance to target decreases (as *other* dolphins can detect).

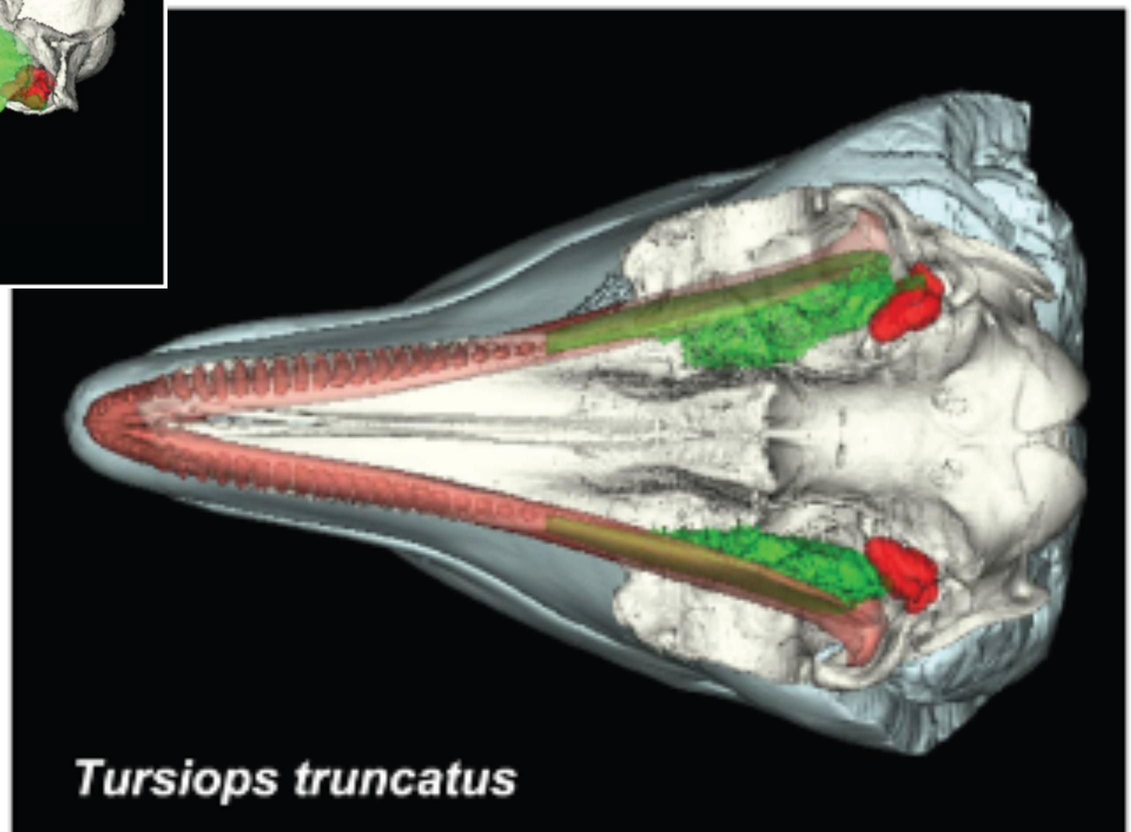
Higher rep-rate sounds (to us) like higher frequency (="TSP", Time Separation Pitch).

* Brand new data (Ladegaard et al 2019) shows that sometimes, in wild, at long distances, do NOT wait for returning echo, but send out <u>close-spaced packets of clicks</u>.

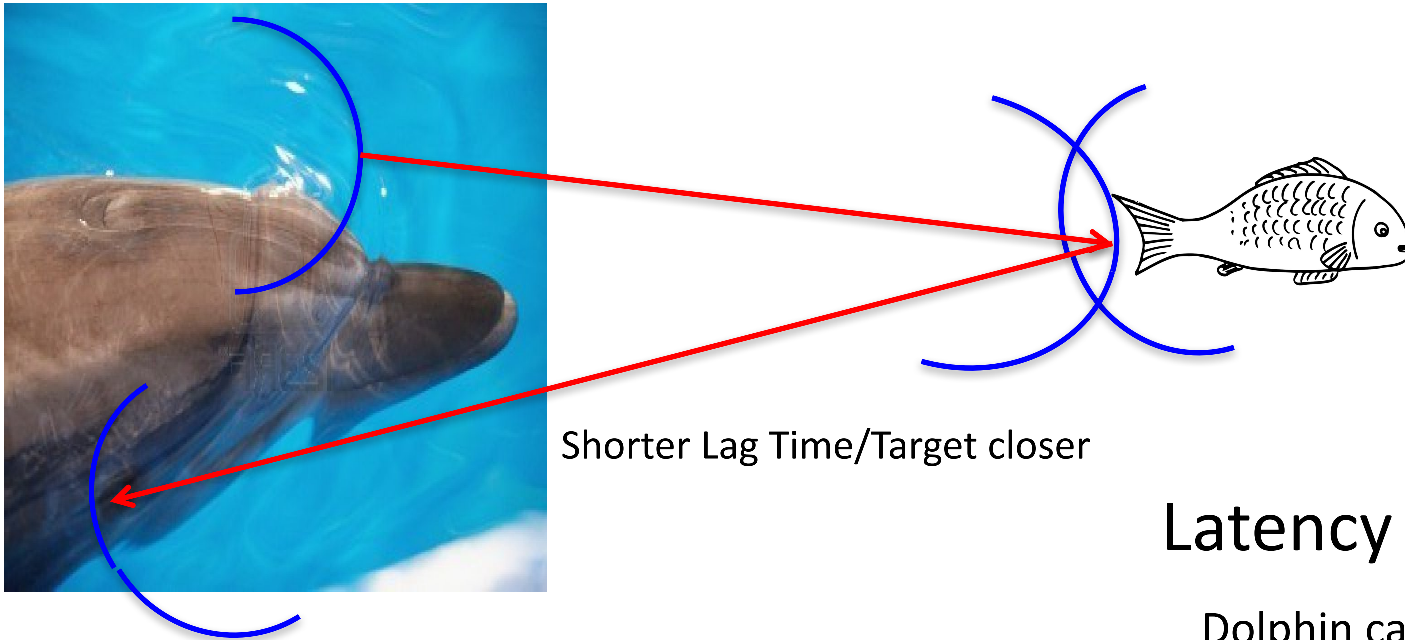
Sound travels through fat in throat & lower jaw to inner ear



Green = Fat
Red = Inner ear

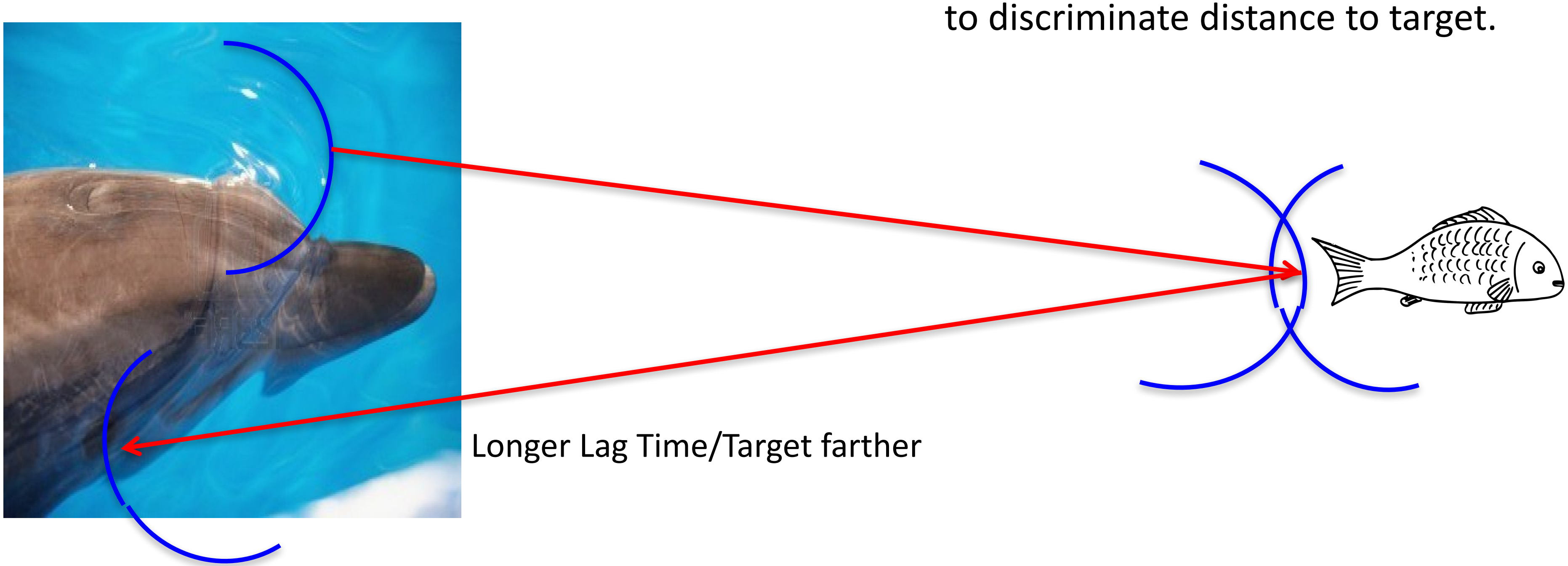


Cranford, Krysl
& Amundin 2010

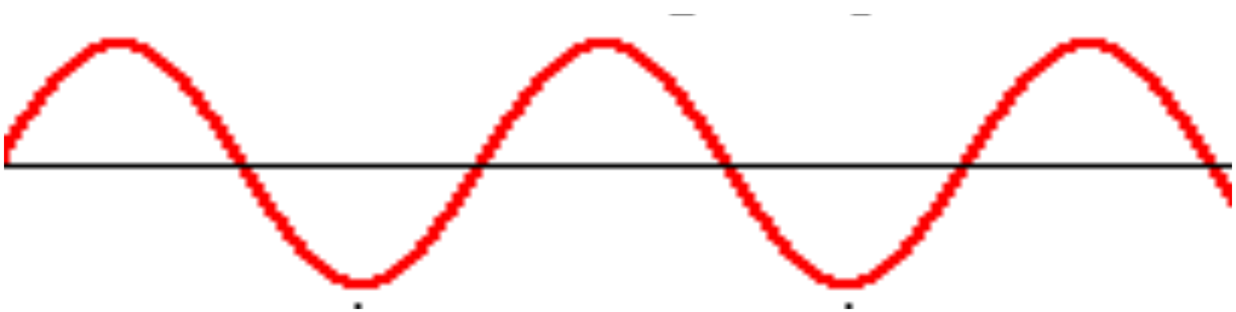


Latency & Distance

Dolphin can use Lag Time
to discriminate distance to target.



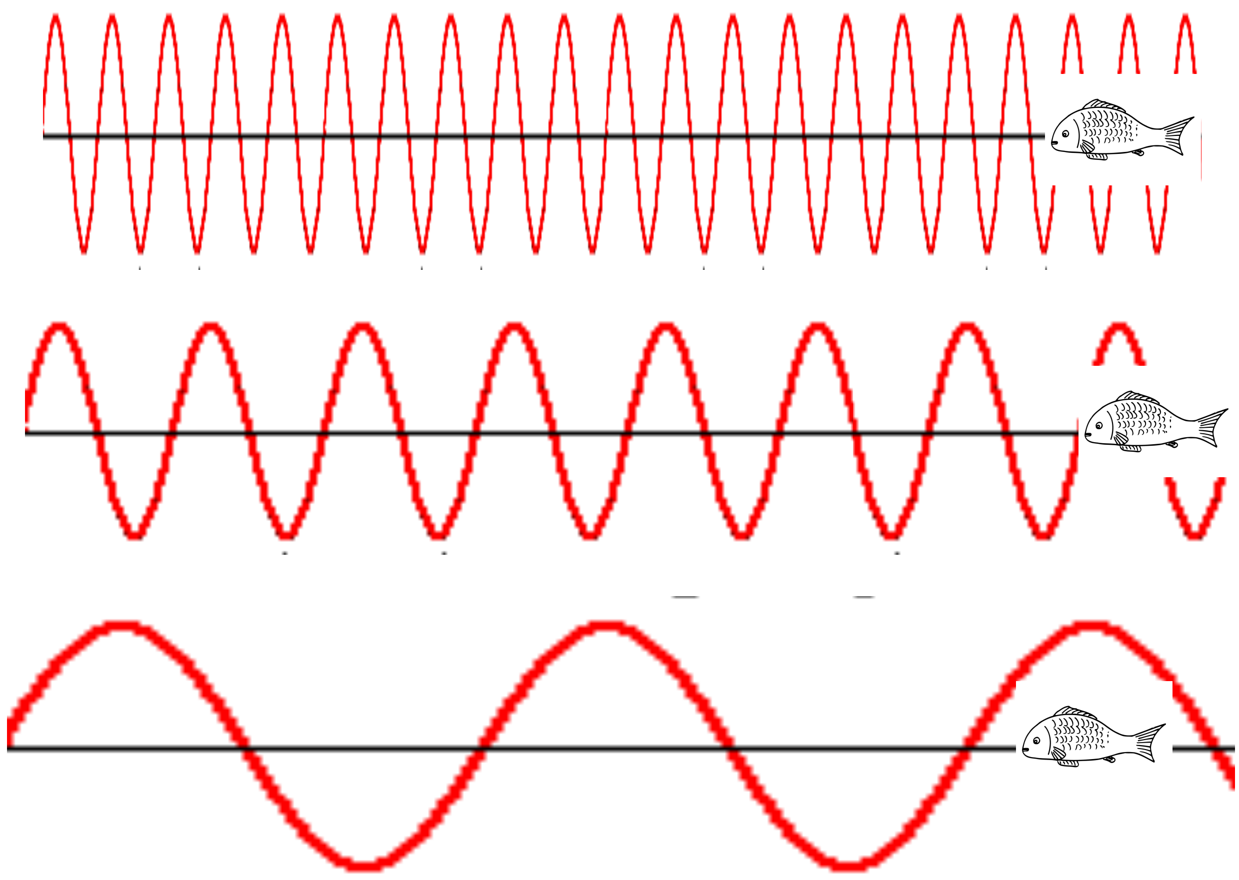
“Broadband” click train simultaneously includes wide range of frequencies



Frequency & Target Size

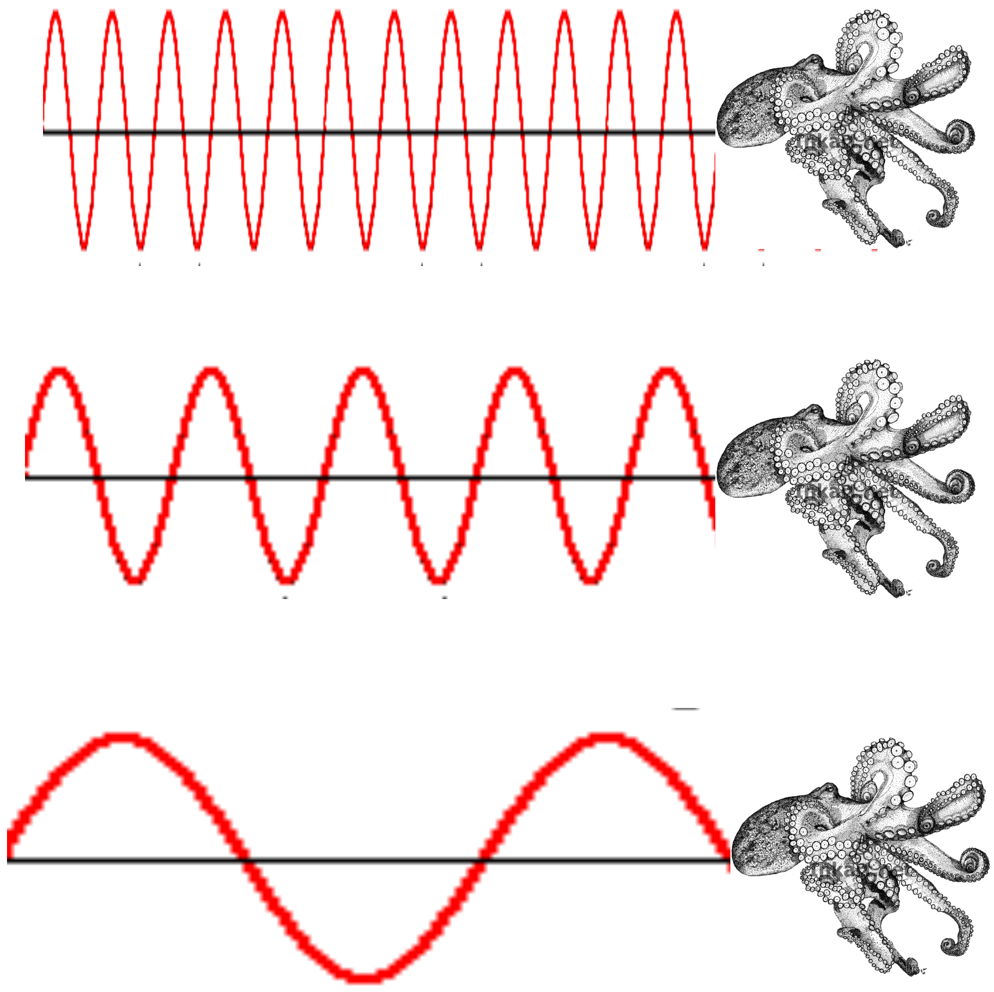
Higher frequencies interact more with small targets than lower frequencies do.

So, an echo from a smaller target will have a greater proportion of high frequencies in it than the original, out-going, “broadband” (muti-frequency) click did.

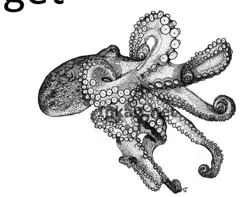


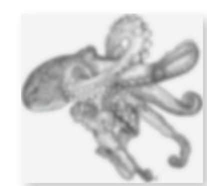
Frequency & Target Detail

Higher frequencies interact more with small targets than lower frequencies do.



Higher frequencies get

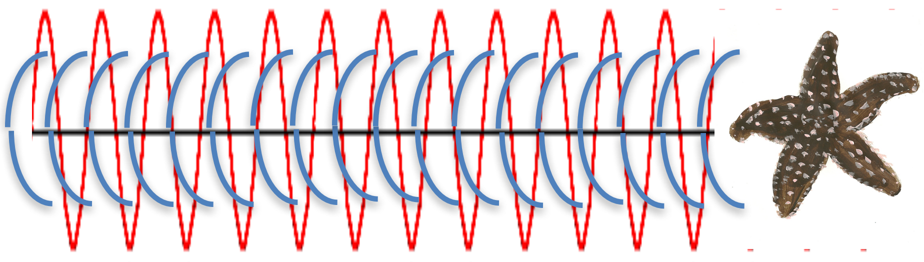


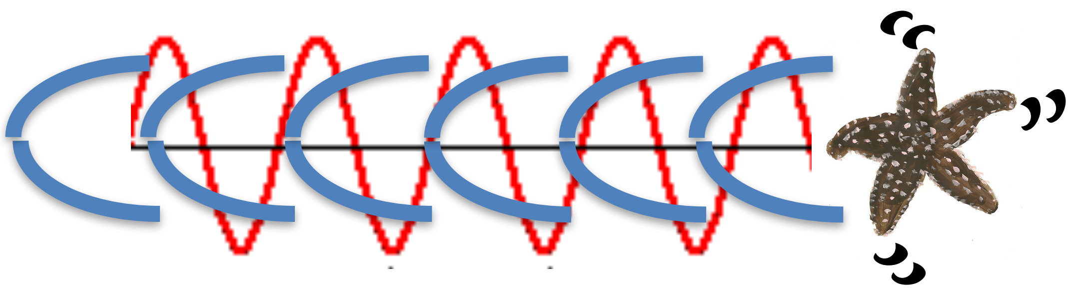


Lower frequencies get lower resolution

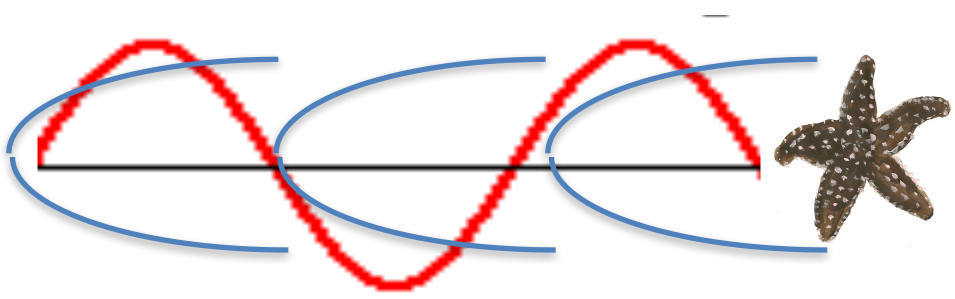
Resonant Frequency Amplified

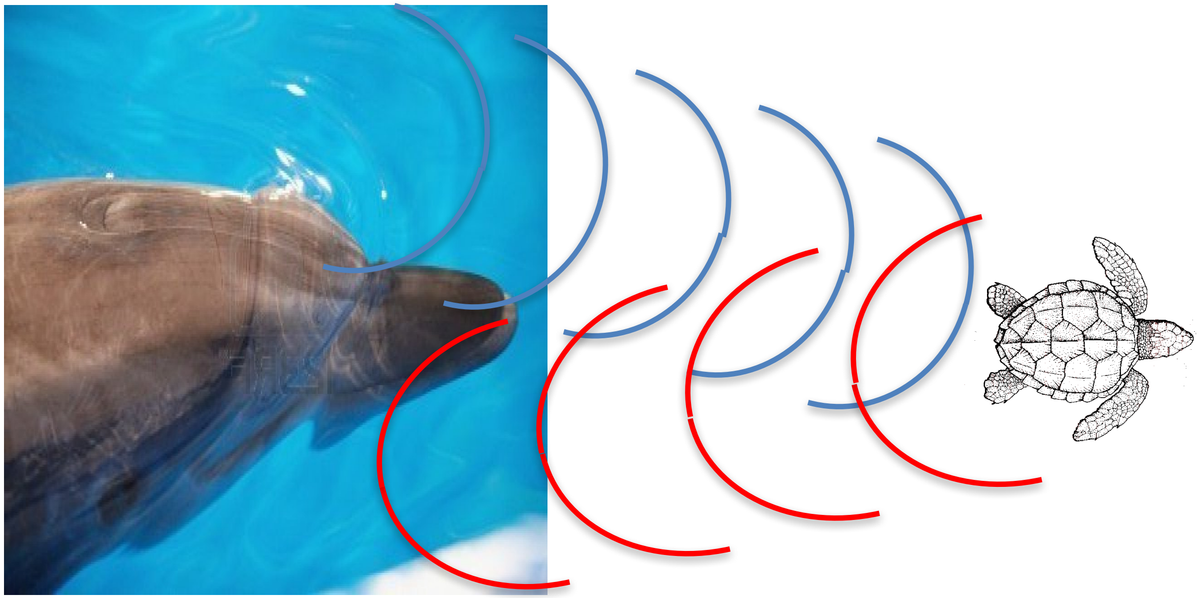
Every object has a specific “resonant frequency”:
When that frequency impinges on it, the object “rings” (resonates).





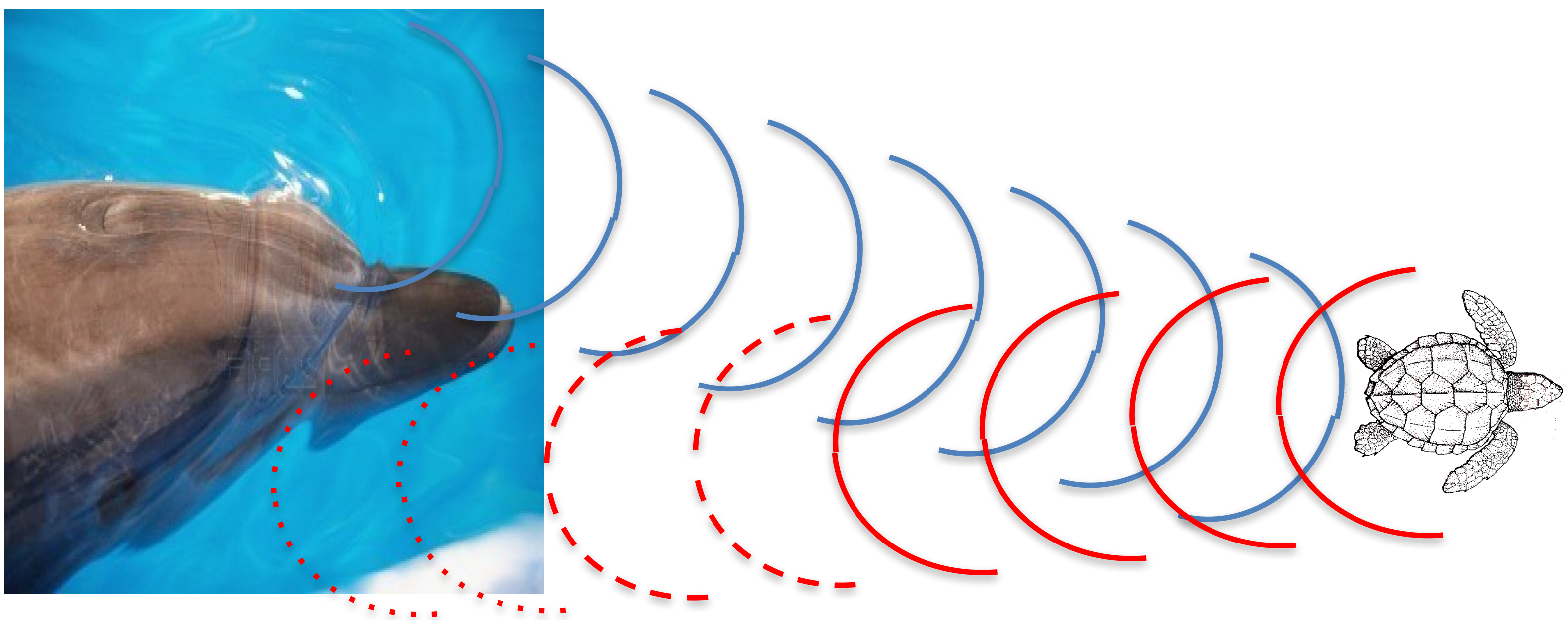
So, resonant frequency will be the strongest (most amplified) frequency in the echo.



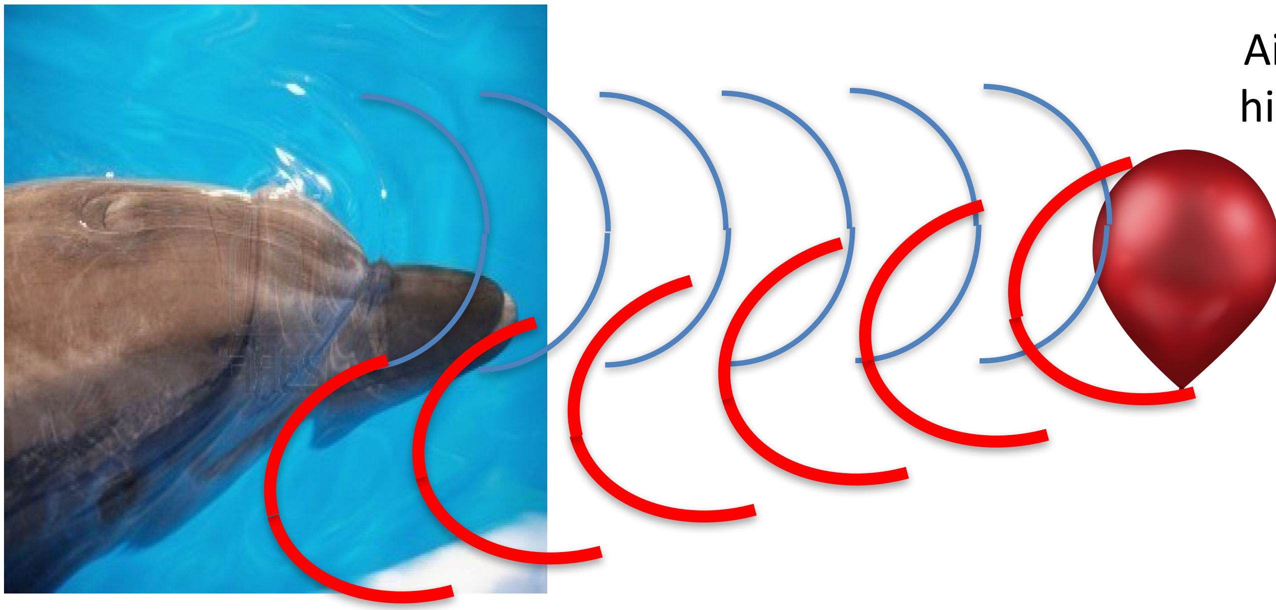


<u>Amplitude</u>

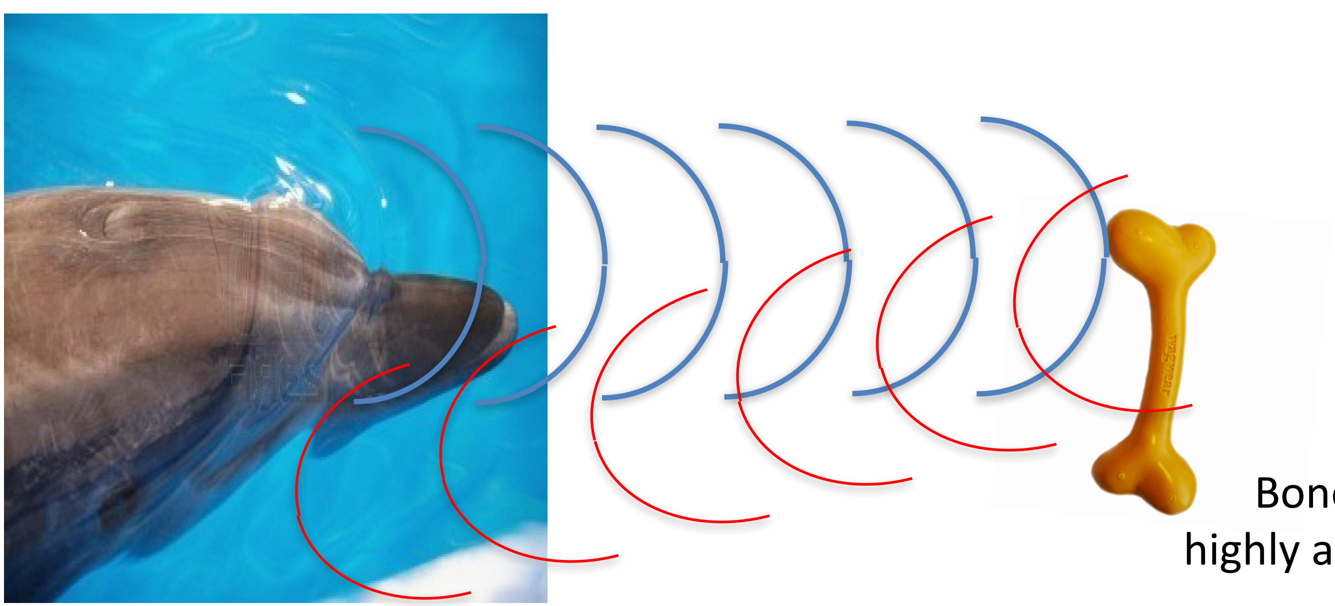
of echo decreases with <u>distance</u> to target



Air pockets are
highly reflective



<u>Amplitude</u>
of echo also depends
on
<u>absorption</u>/<u>reflection</u>
by target



Bones are
highly absorptive.

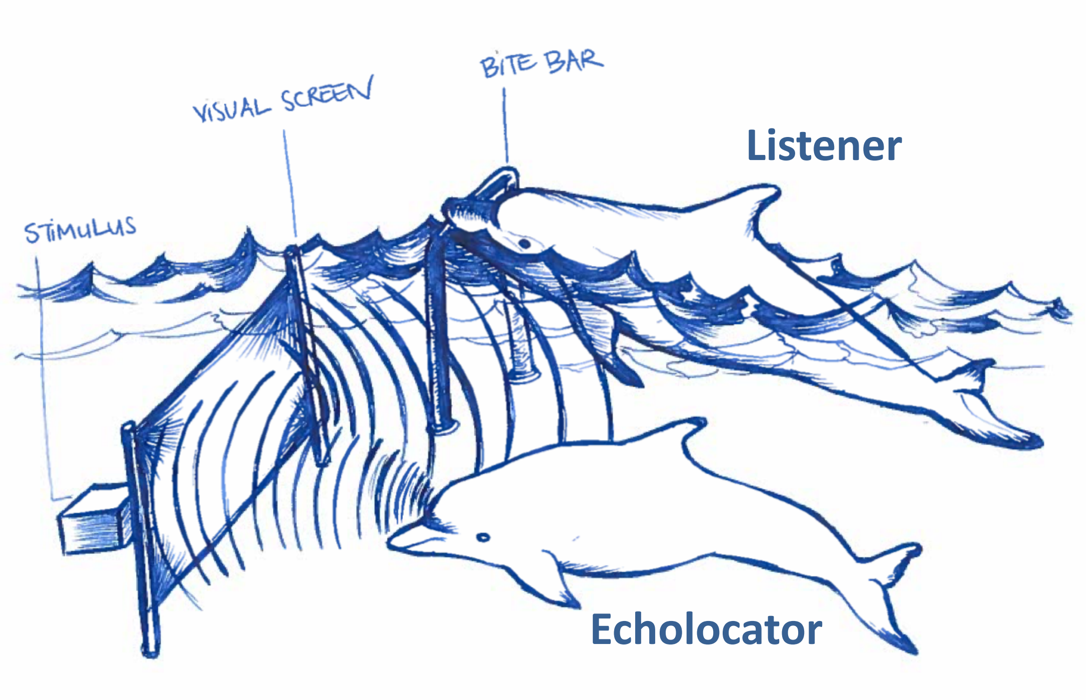
<u>Learning</u> plays an important role in development of Echolocation

"Baby position" puts infant in ideal position to listen-in to mother's echoes

Listening In…

Xitco & Roitblat (1996)

Listener can accomplish *some* discrimination with access to echoes only



Listener on "bite-bar", can hear through jaw but not echolocate

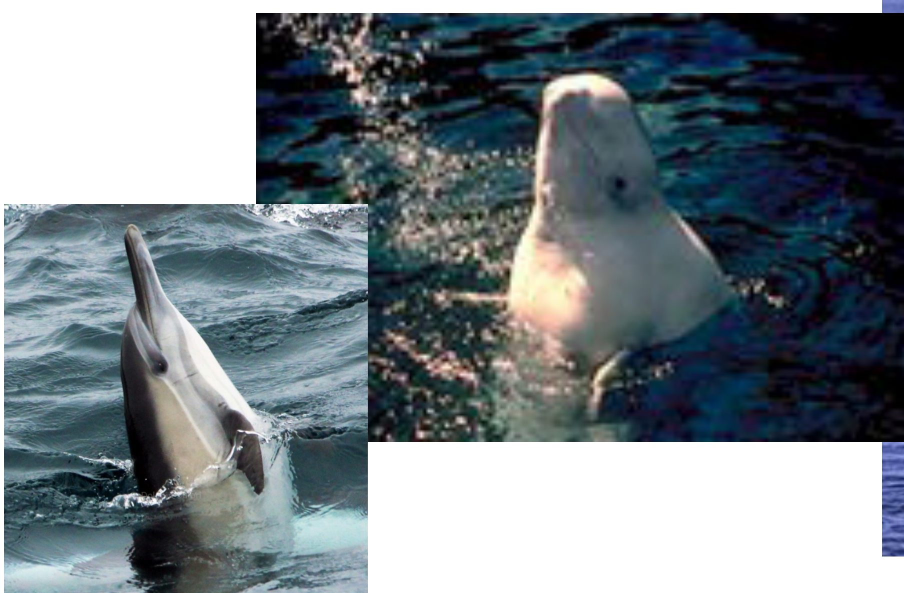
Echolocator, buzzes objects behind visual screen

Listener can select object of matching material, tho looses access to some detail.

Vision - Also used in hunting

- **Spy Hop** – Locate prey, conspecifics,
  birds circling over/feeding on fish schools, etc.

- Eyes specialized to <u>see farther in air</u> than in water
  - i.e. Weird pupils squeeze down to limit light
    (discrim WIDE range of intensities)
    and enable to see farther in air



Vision - Also used in hunting

Lou Herman's Cognition Lab,
University of Hawaii
Starring Phoenix & Ake

Vision - Also used in hunting

- Especially <u>sensitive to **contrast** & **motion**</u>;
  - Can see prey (and each other) well, esp at close range
  - Original visual MTS tasks failed to take this into account...

e.g. Present color stimuli

Sample

Vision - Also used in hunting

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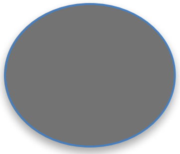
Sample



But this is what dolphins see!

No surprise,
they failed the task

Vision - Also used in hunting

- Task modified to using high-contrast, moving, 3D stimuli
    - Success!

+

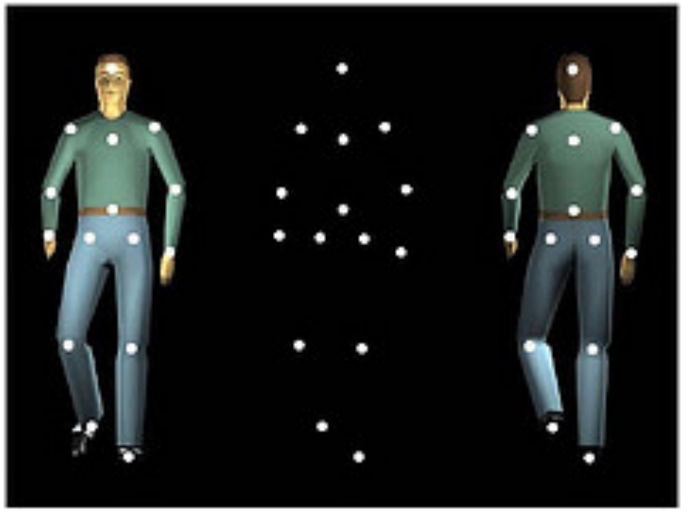
Via improved **Ecological Validity**

Vision - Also used in hunting

IN OTHER WORK

Reduced moving trainer gestures to point-light displays.

Dolphins had no problem following commands, even with such degraded input



For demo of above, see: https://www.biomotionlab.ca/Demos/BMLwalker.html

(Using equivalent of primate **STS** for for recognizing biological motion?)

Ecological & Cultural Constraints

- Orcas off the NW coast of N America live as **<u>Transients</u>** or **<u>Residents</u>**

- **<u>RESIDENTS</u>**
  - Groups composed of <u>extended family</u> units
  - Work together to herd, eat <u>fish</u> (mainly salmon)

Ecological & Cultural Constraints

- Orcas off the NW coast of N America live as **<u>Transients</u>** or **<u>Residents</u>**

- **<u>TRANSIENTS</u>**
  - Smaller pods, range widely
  - Diet includes <u>other marine mammals</u>
    - e.g. Stealthily capture seals onshore
      - Unite to take large whales
      - Coordinate to wash seals off ice flow, etc

Ecological & Cultural Constraints

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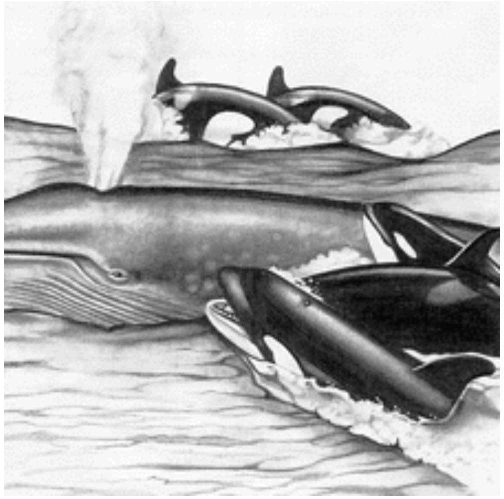


PLUS

- Residents **noisy** when hunt fish
  - Can shift echolocation to emphasize higher freqs than most fish hear

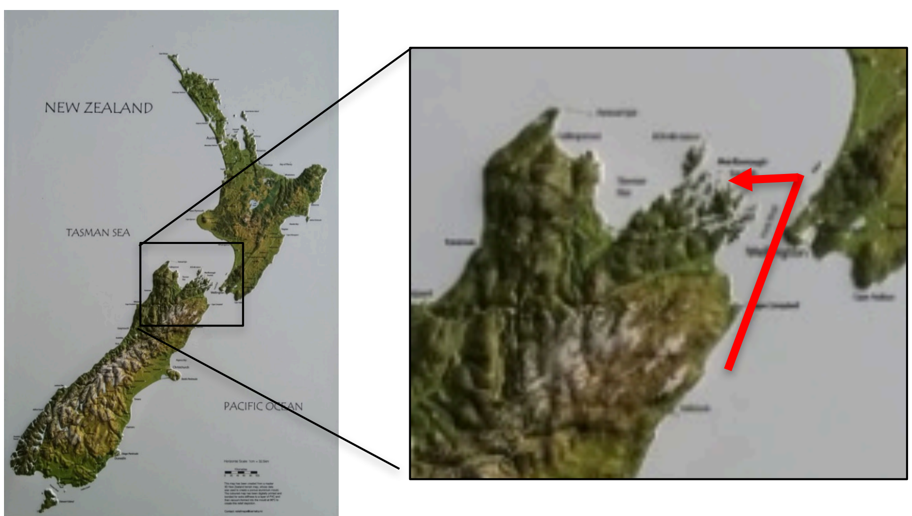
- Transients **silent** when hunt (acoustically sensitive) marine mammals

- Same species, so likely these are “cultural” differences
  - Indicates adaptability of the species

Ecological & Cultural Constraints

- New Zealand **Dusky Dolphins** (community pop ~1,000)
  - Small dolphins, heavy predation pressure
  - Large, fission/fusion groups rest (& socialize) in shallows in day; Some alert for predators
  - Small groups feed offshore at depth at night
- In winter, *some* travel 170 miles
  - From Kaikoura to Admiralty Bay
  - There, all rest in large groups at night
  - Feed in small, fixed groups in shallows in day

(See *Wursig & Pearson* reading)



- Note, these <u>Day/Night</u> & <u>FF/Fixed reversals</u> are only done by a sub-population
  - A "cultural" practice?
- Requires considerable <u>adaptability</u>

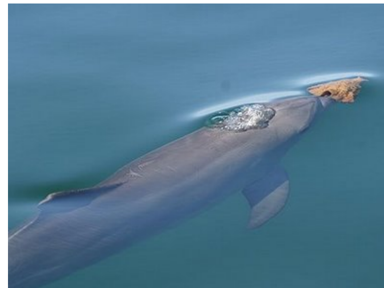
Coastal dwellers are different

Coastal habitats: May provide more options:

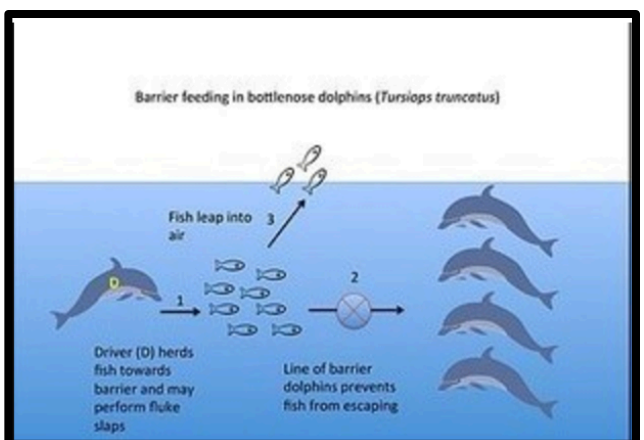
Prey vary in sea grass, coral reefs, sandy bottom, estuaries etc.

Ecological & Cultural Constraints

- Bottlenose dolphins show <u>great variability</u>
  - Kerplunking
  - Sponging
  - Beaching prey
  - Crater fishing, etc etc.

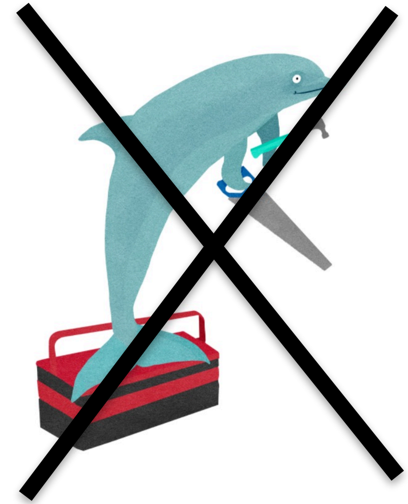


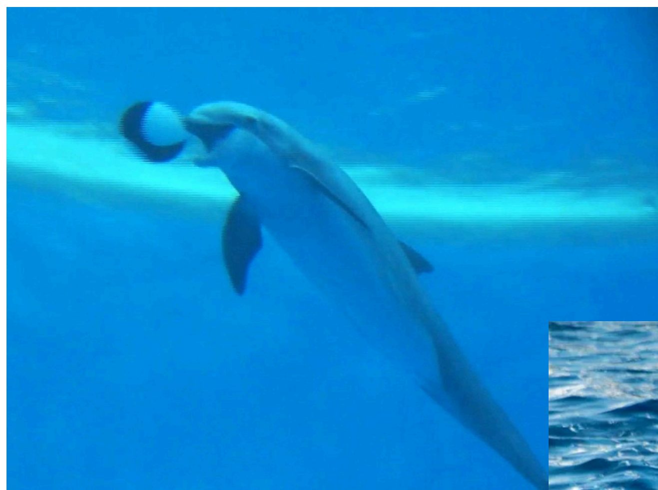
- Includes local traditions that
  vary across diff populations
  of same species   (More later!)



Tool Use

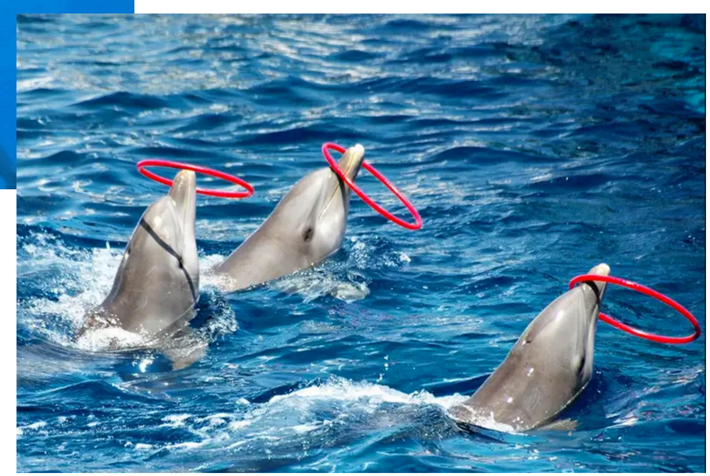
- No (useable) fingers!
- But do occasionally manipulate non-food objects
- NOTE: We humans tend to focus on this!





In Captivity:

- Enjoy playing w/objects
- <u>Invent</u> novel uses
  - e.g. Poke feather in hole to roust eels
- Sometimes <u>imitate humans' use</u> of objects
  - e.g. Hold algae scraper in teeth, clean window



Tool Use

- In experiments, can be trained to manipulate apparatus, poke sticks into tubes, boxes, etc. for reward

- The military trains dolphins to ...
  - Deploy uw cameras,
  - Attach locator beacons to sunken objects,

Tool Use

Occasionally seen to play with, manipulate objects in the wild

WORK (Foraging):
Shake Conch, to get hidden fish

PLAY: "Jewelry"
Bubble rings

Tool Use

"Sponge Carrying"

Tursiops aduncus
(off E. Australia)
used (?) to forage on bottom

Only a few practice this,
but have passed tradition on
to (esp) their daughters

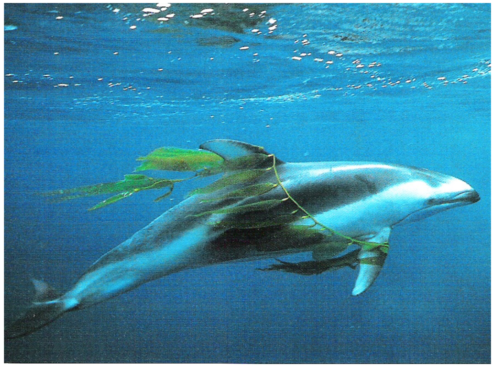
Tool Use

Above reflects less a (primate-like) obsession with “stuff” than a

<u>general flexibility/inventiveness/adaptiveness</u>





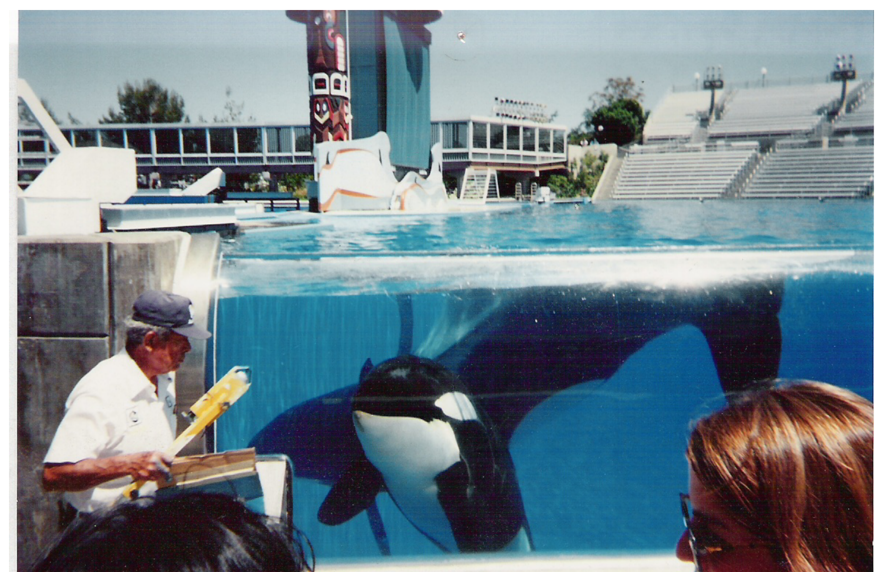



Curious!

Cooperate with fishermen, helping drive fish into nets, for a share

Jean Asbury offers Dolly a fish from her mouth.

Individual wild cetaceans will come and investigate, befriend humans



Similarly, captive animals attend to activities outside their tanks

Creative

Can learn command that means “do something NEW”!

Tandem Creative!

Can even be trained in pairs to create something <u>new, together</u>, on the fly!

Probably related to amazing synchronous displays in wild…

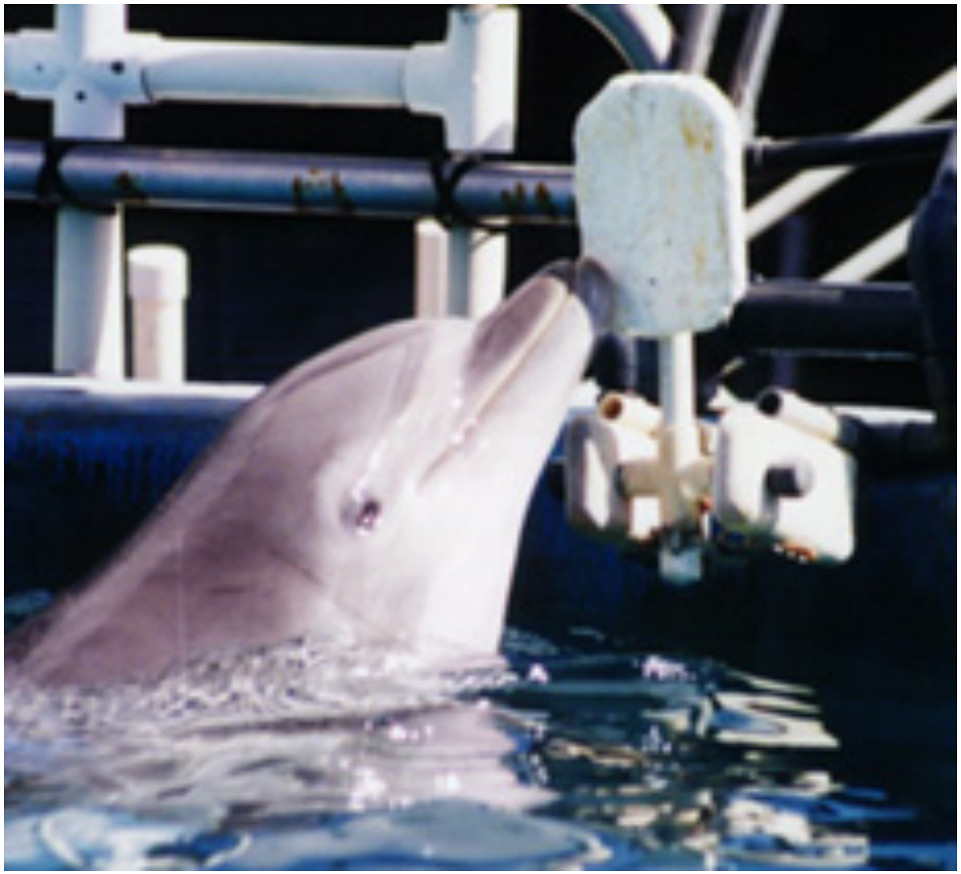
Ecologically Relevant "Objects"

- While dolphins do NOT (compared to primates) do much object/tool manipulation,
  PREY are objects too!
  - Need to be found, identified, processed, just as primates' foods do…

- How do dolphins discriminate, track "things" in the cluttered, dynamic ocean??

Object Permanence

As would be expected (esp for hunters) dolphins readily show Object Permanence



e.g. In language studies, use

"No Paddle" to report

absence of requested object

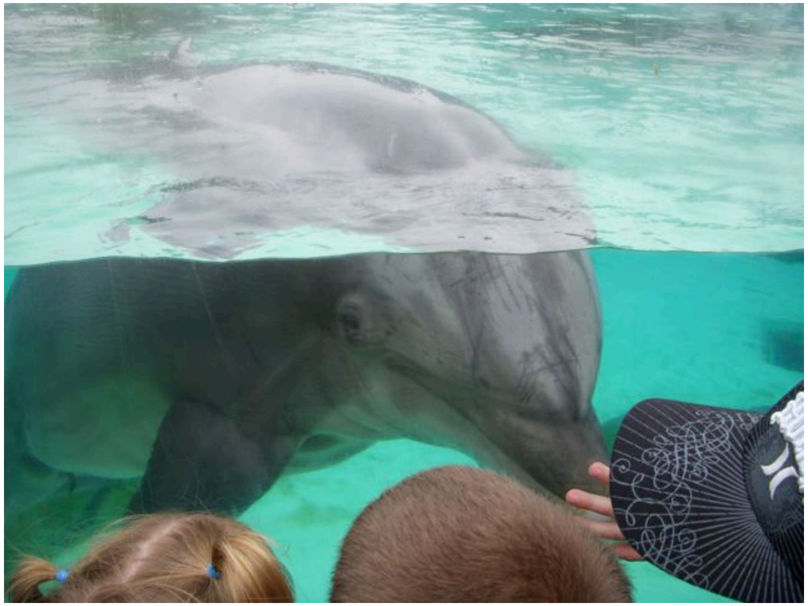
Behavior suggests develop "**search image**" for requested object

- Trainer signals "Hoop Fetch" (no Hoop in pool), Dolphin searches, presses "NO" paddle
- Trainer signals "Frisbee Hoop Fetch" (= "Take Hoop to Frisbee", no Frisbee); takes Hoop to NO

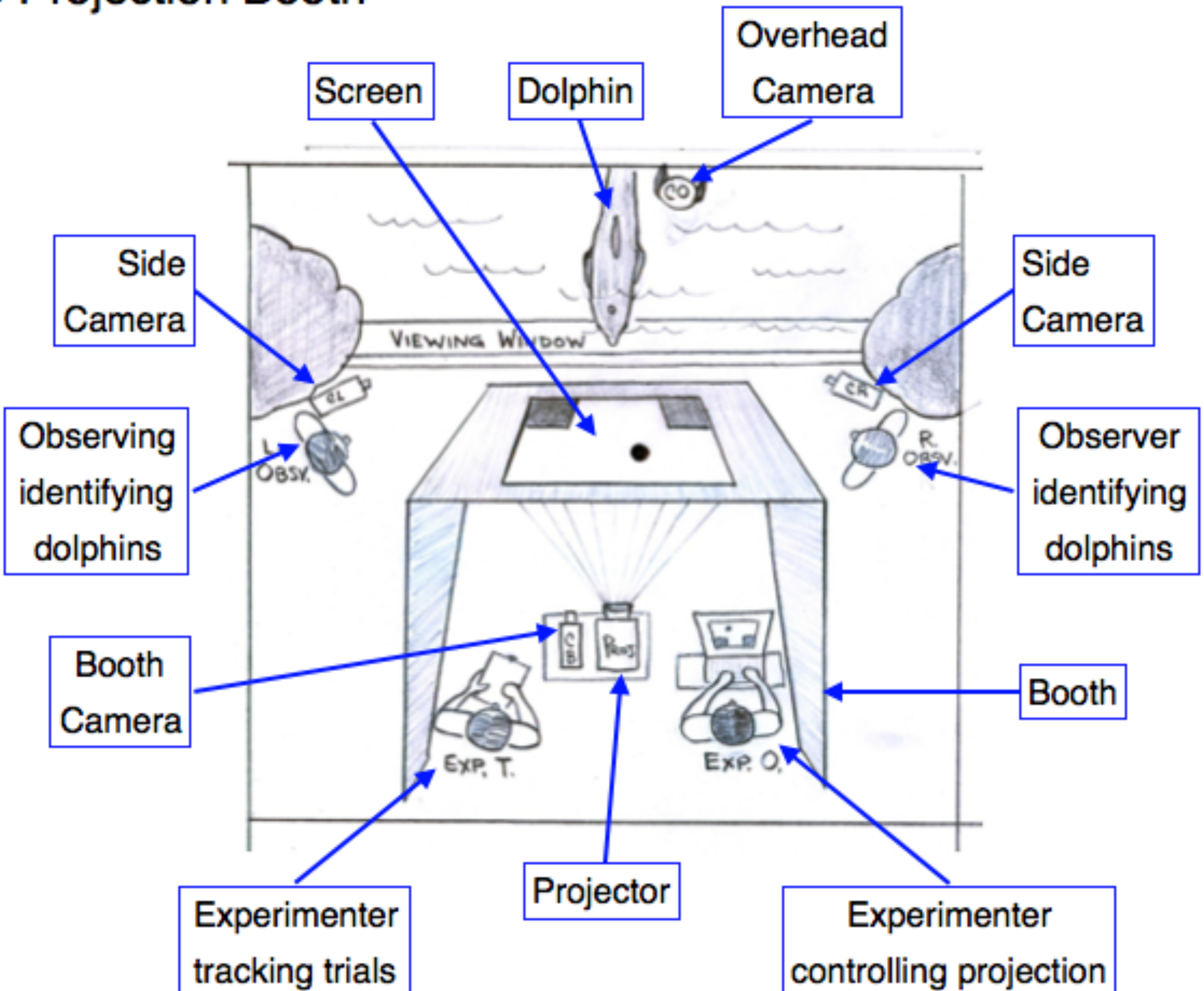
Visible & Invisible Displacement

We have done some research on this subject...

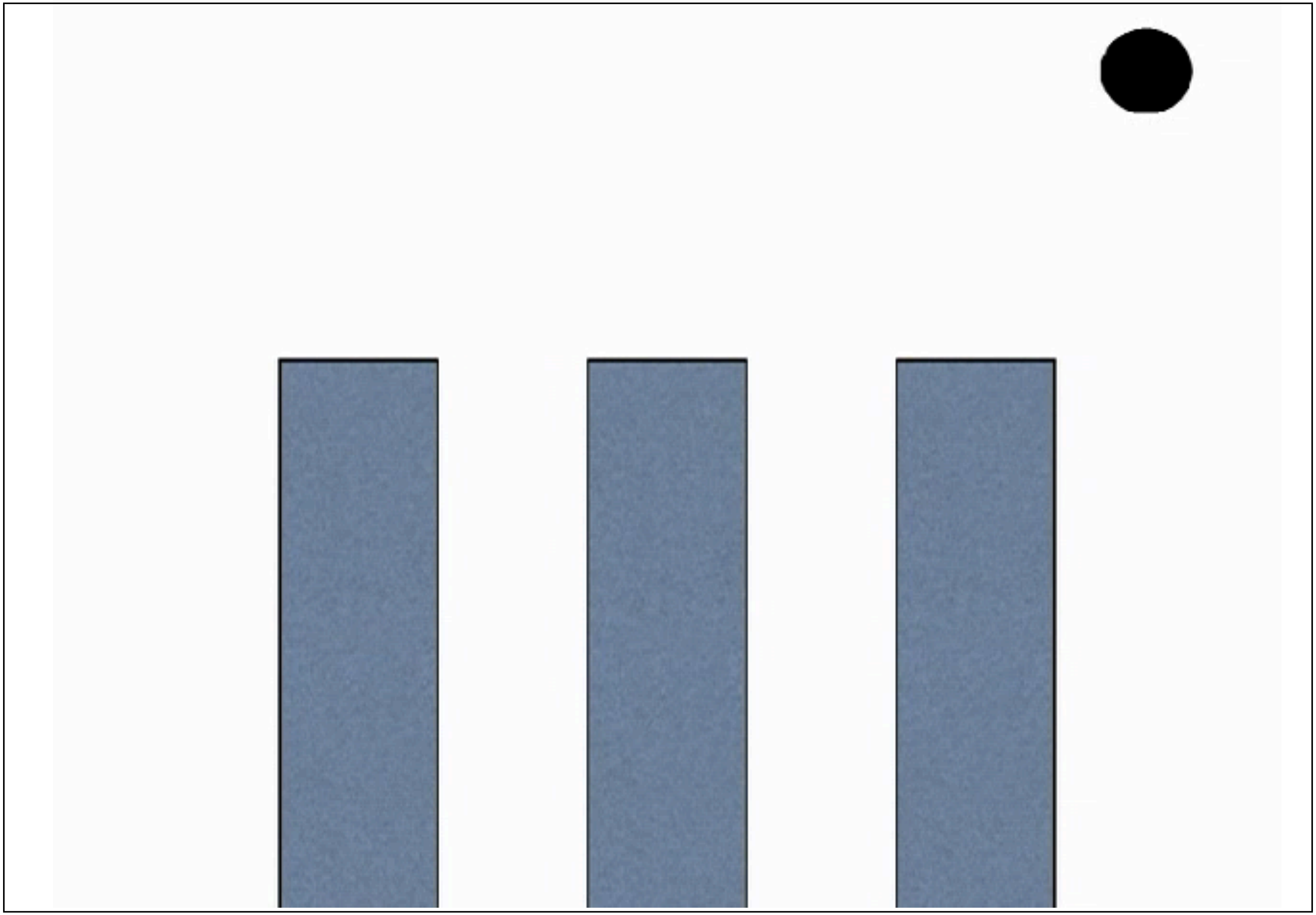
- Setting & Subjects
  - "Rocky Point Preserve" - Petting Pool at Sea World San Diego
    - Viewing window 16' X 4.5'
  - 8 to 16 Bottlenose dolphins (*Tursiops* spp.)
    - 1-37? years of age, 3 males



Video Projection Booth



Object Permanence



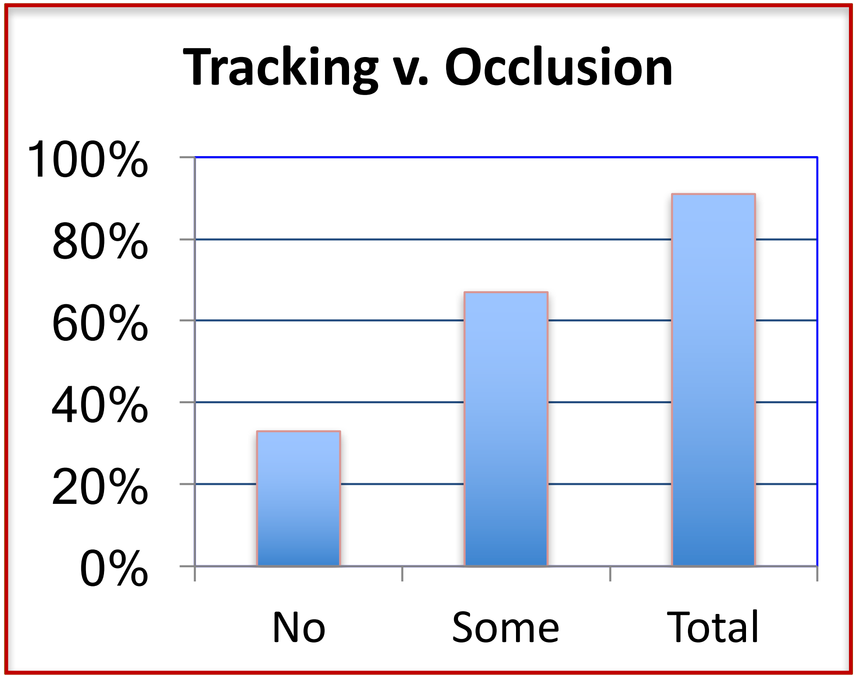
Object Permanence

Object Permanence

RESULTS: Dolphins capable of tracking object they see move behind occluders

i.e. show "Object Permanence" (AKA "Visible Displacement")

- Tracking varied with Occlusion
  - No occlusion: Tracked 33%
  - Some Occlusion: 67%
  - Total Occlusion: 91%



- Does head motion serve as a mnemonic when direct info least available?

Invisible Displacement

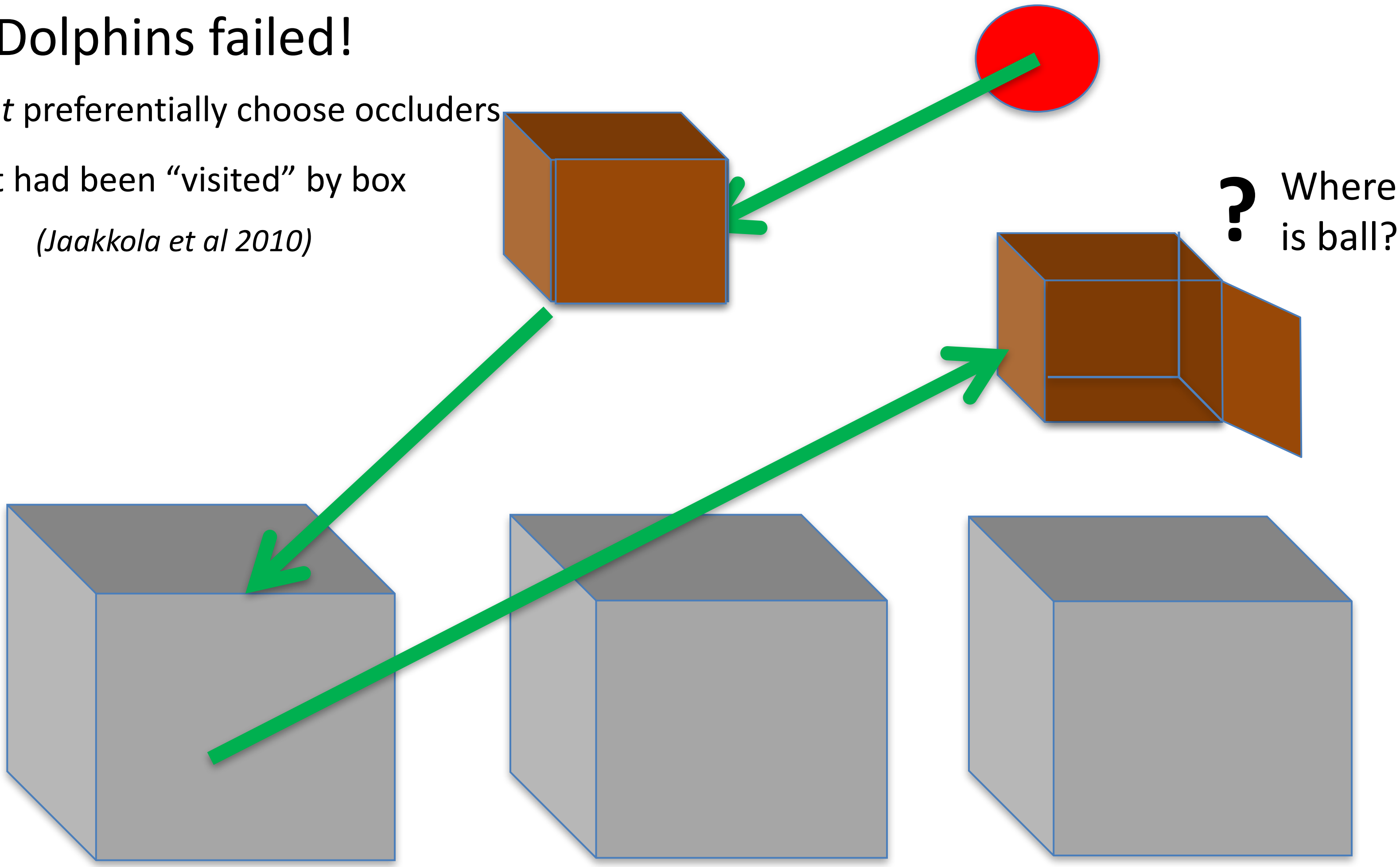
As with primates, dolphins were tested on sequential containment . . .

Dolphins failed!

i.e. Did *not* preferentially choose occluders

that had been “visited” by box

(Jaakkola et al 2010)

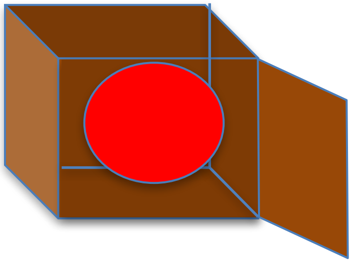


<u>Box-with-Ball</u> temporarily <u>disappears into</u> only certain Occluders, before revealed as empty

Invisible Displacement

When their performance is so similar on many other tests,
why should apes (and some monkeys) <u>succeed</u> at Invisible Displacement
while dolphins fail?

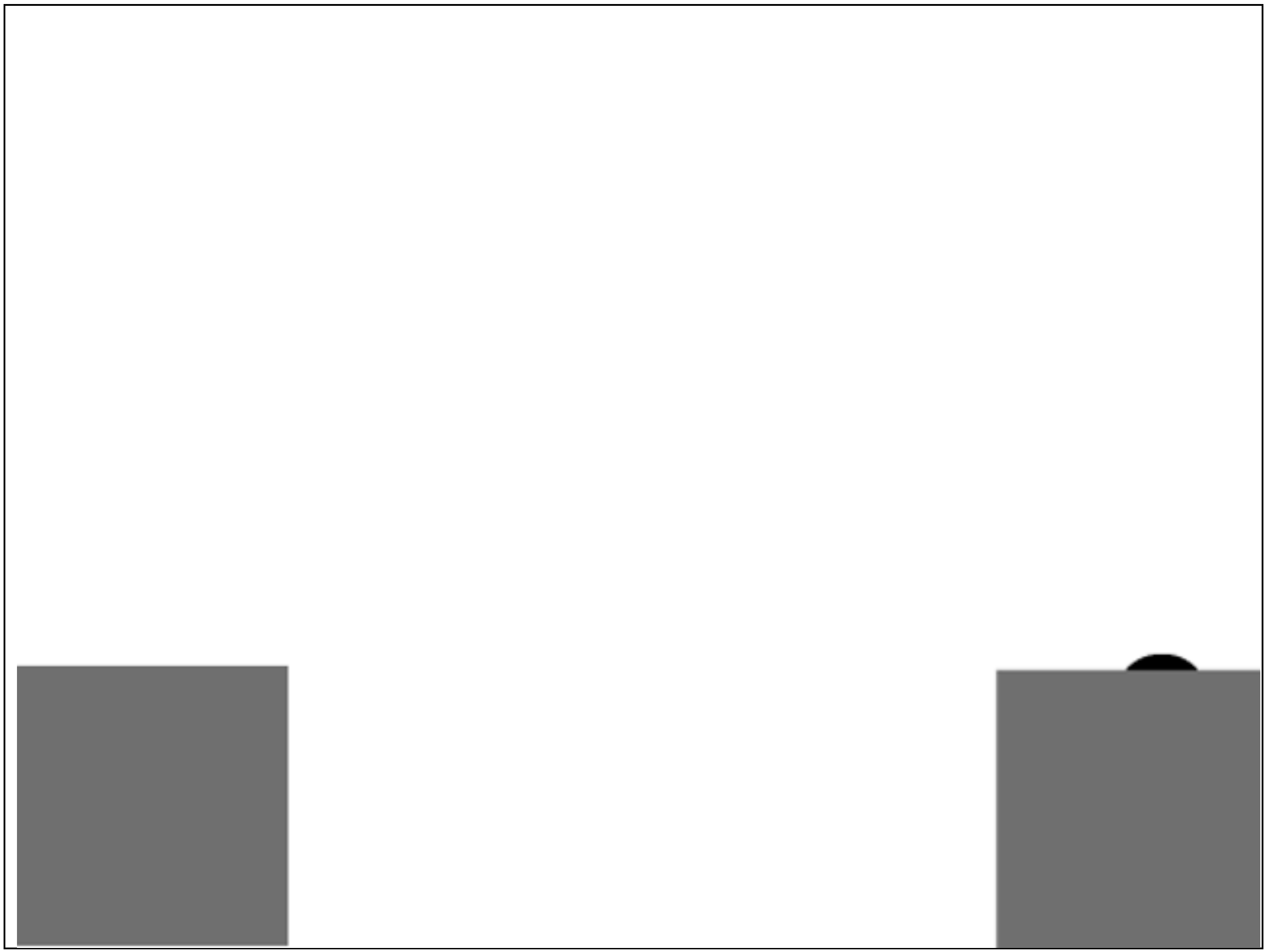
Perhaps because "<u>containment</u>" is (relatively) alien to the hand-less dolphin…??



So, we decided to try a version of this task that was more **Ecologically Valid..**
(Johnson et al., 2015)

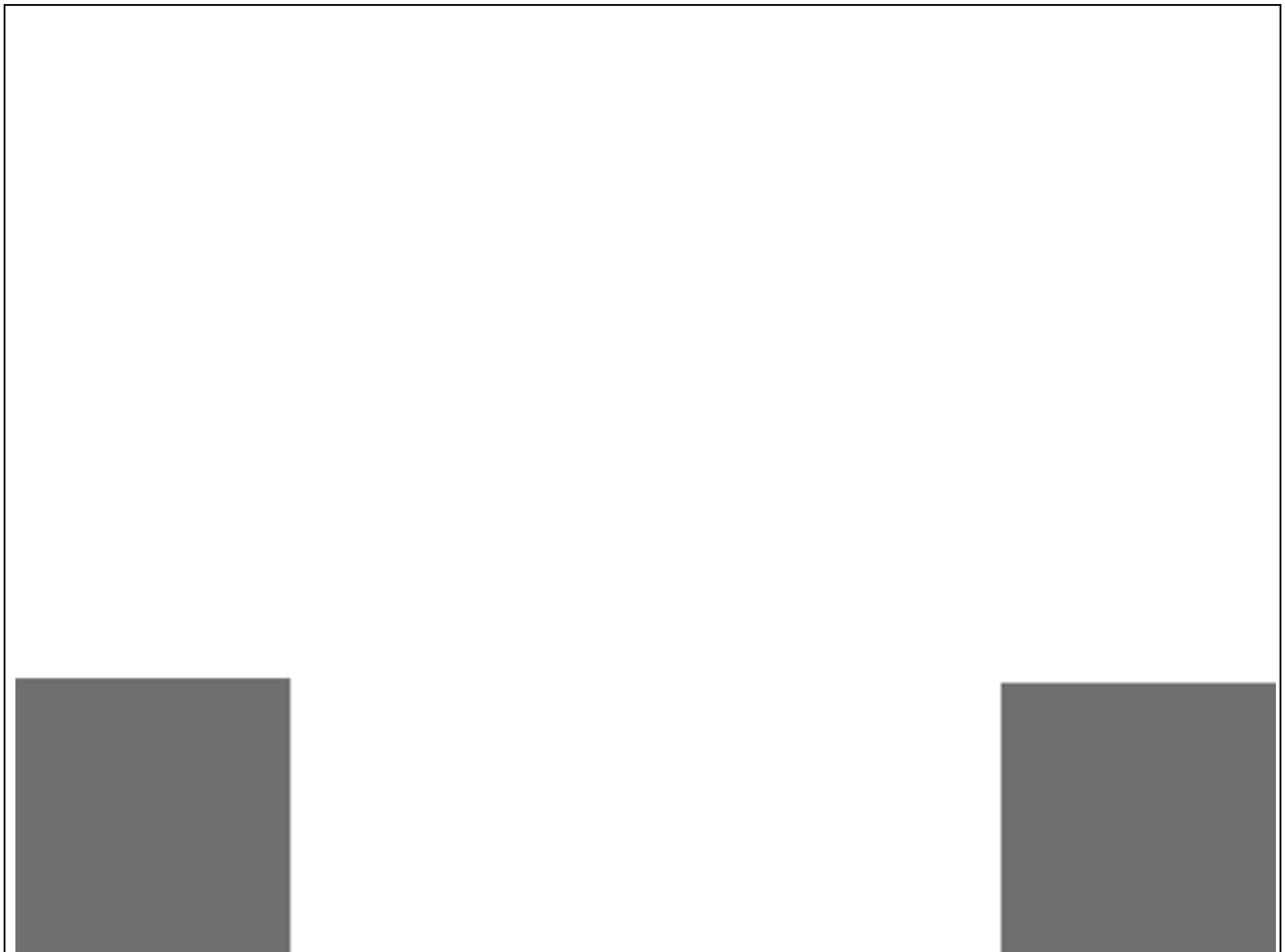
Invisible Displacement

- Invisible Displacement
  - Establish “world” through pre-videos
    - **BALL** - Quick, erratic, sometimes lingers behind occluder



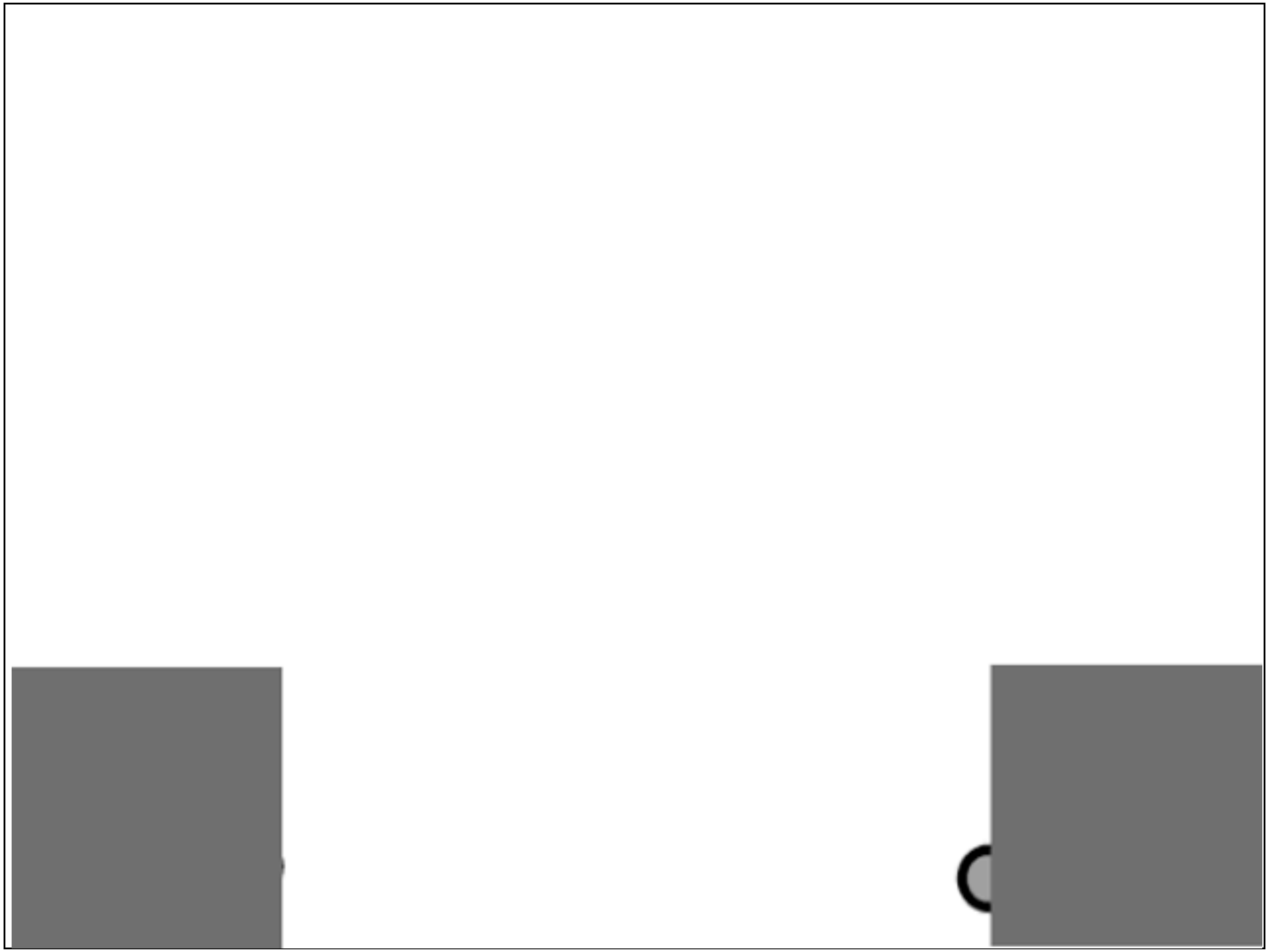
Invisible Displacement

- Invisible Displacement
  - Establish “world” through pre-videos
    - **SAUSAGES** - Alone or together, slower regular paths, sometimes temp. occluded



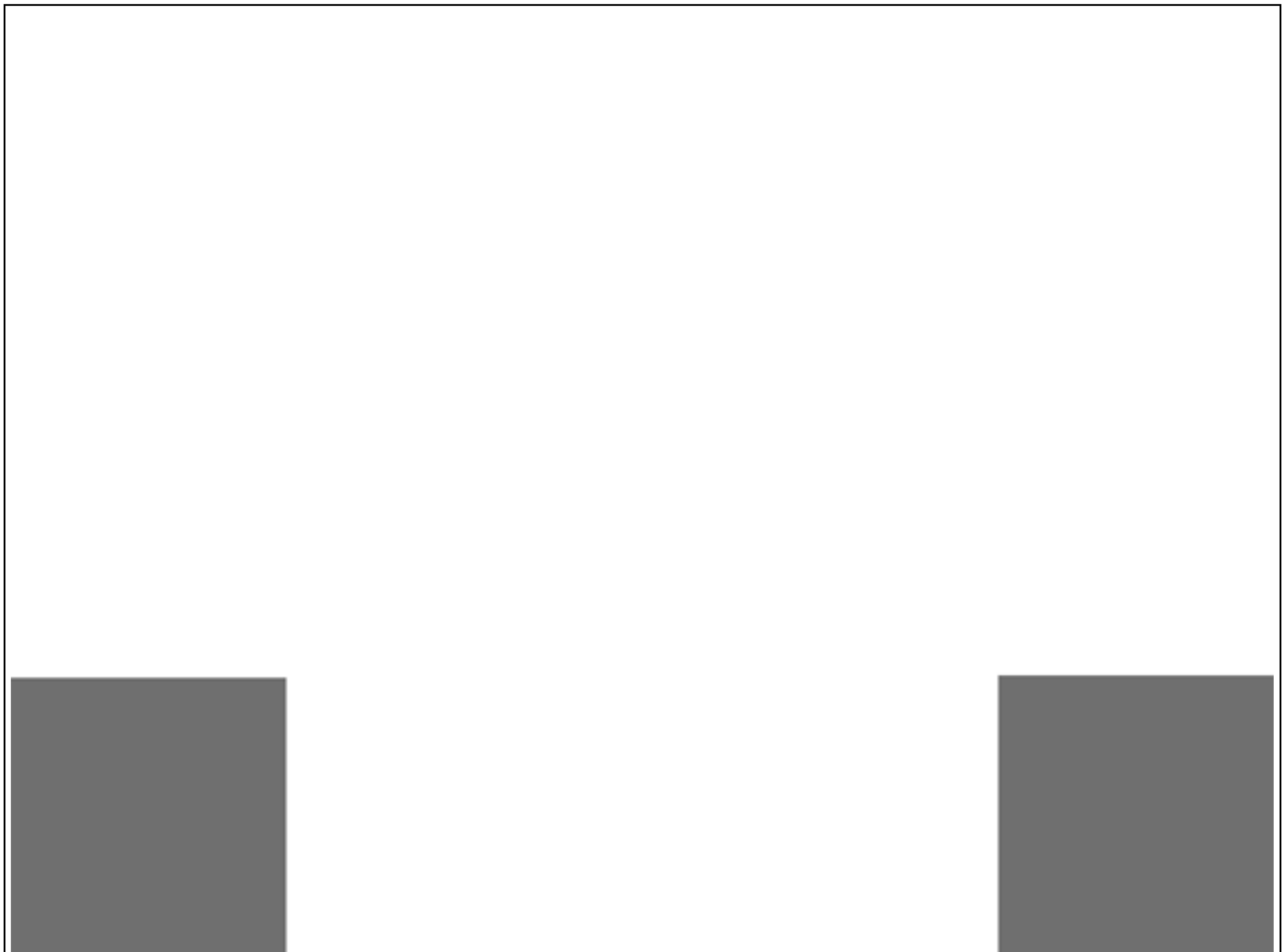
Invisible Displacement

- Invisible Displacement
  - Establish “world” through pre-videos
    - BALL joins, leaves, is only **partial**ly occluded by **one** SAUSAGE when move together



Invisible Displacement

- Invisible Displacement
  - Establish “world” through pre-videos
    - BALL joins, leaves, is **fully** occluded by **paired** SAUSAGES

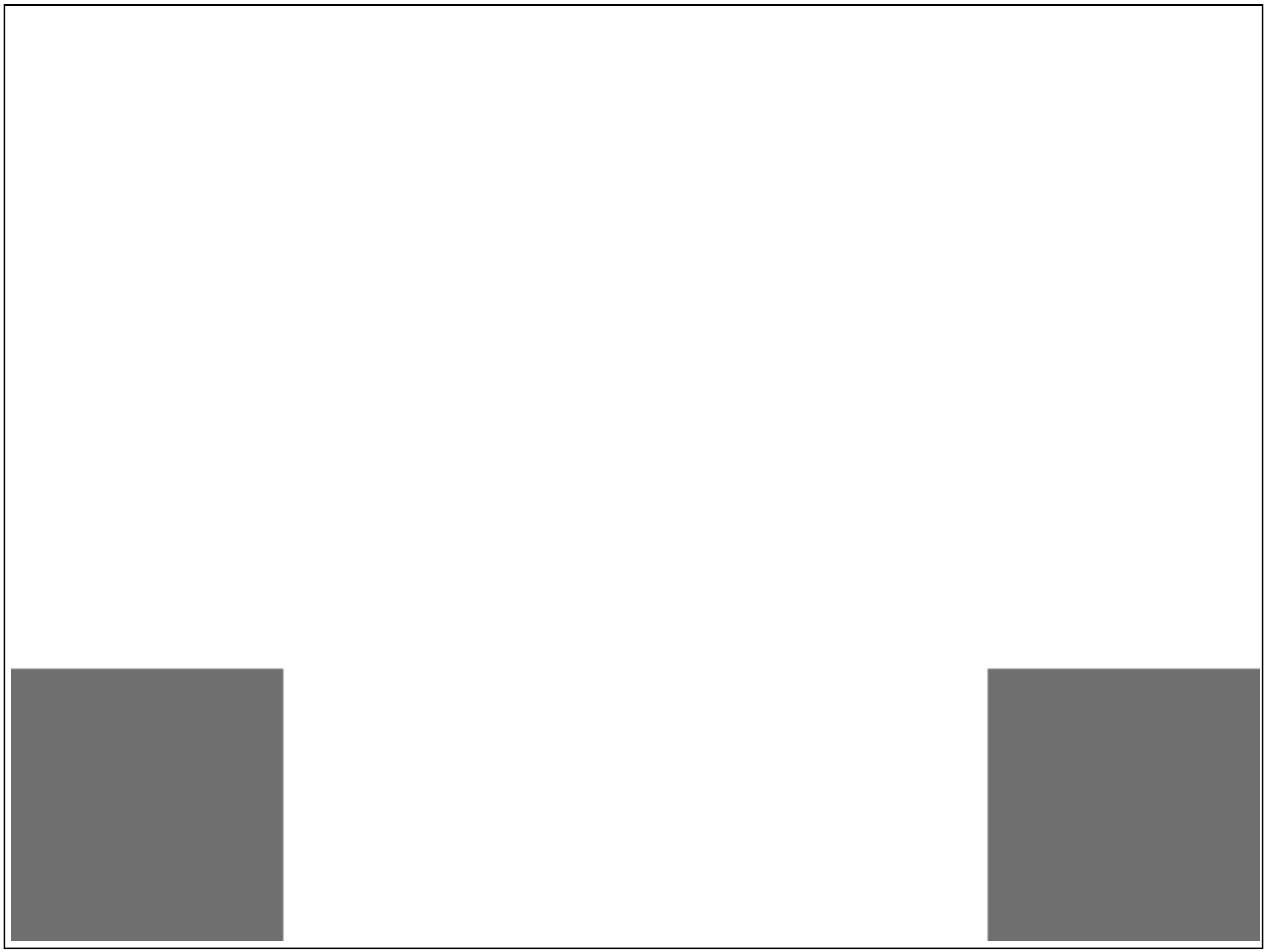


Invisible Displacement

- Invisible Displacement
  - Establish “world” through pre-videos
    - BALL can be **revealed** from behind SAUSAGES when they split up

Invisible Displacement

- Invisible Displacement
  - **Test**: BALL occluded behind two SAUSAGES, that then go behind 1 of 2 occluders
    - When revealed Ball not still behind,will dolphin look toward appropriate occluder?



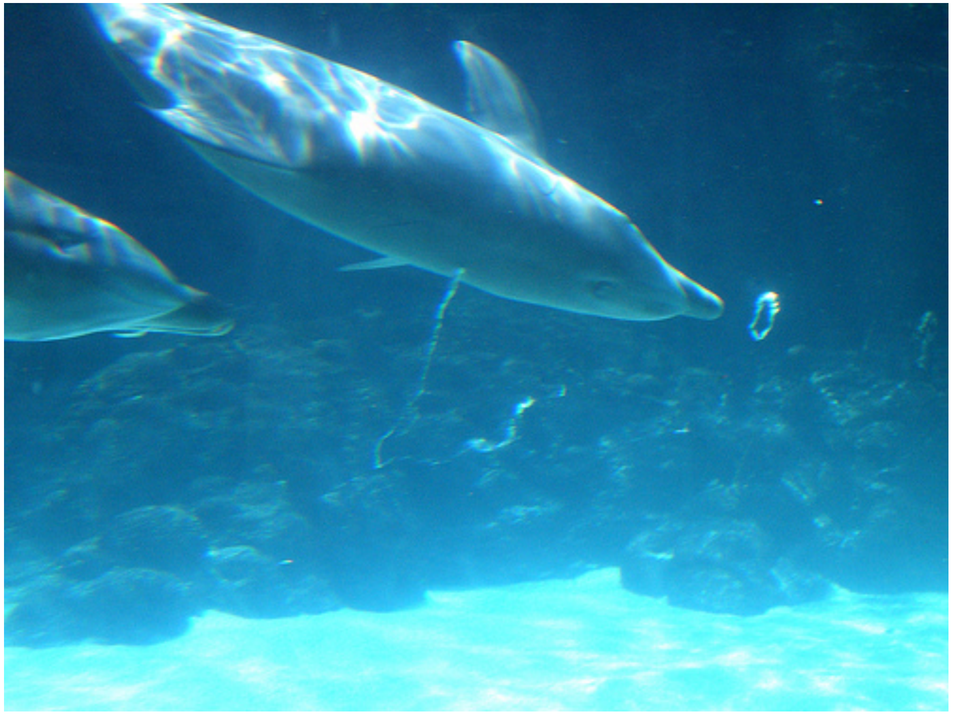
Invisible Displacement

- Dolphin Reaction - CAPTAIN

Invisible Displacement

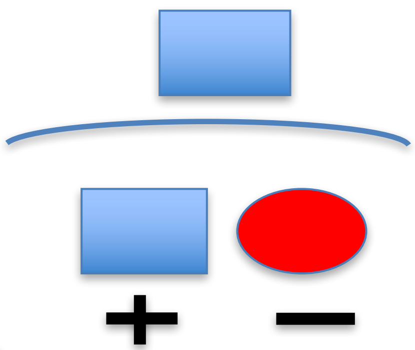
RESULTS:

- Sausages Only:
  - 50% follow right/left
- Sausages + Visible Ball:
  - 80% follow ball not sausages
- Sausages + Invisibly-Displaced Ball:
  - 78% look to where ball invisibly displaced !
- Ecologically valid success!

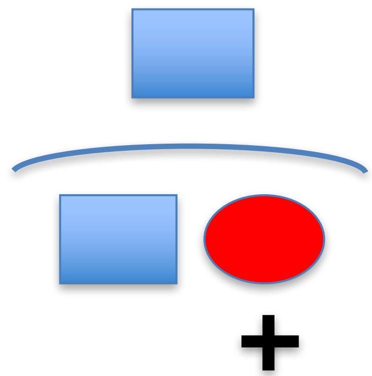


“Rule-Based” Learning

“Identity” MTS



“Oddity”



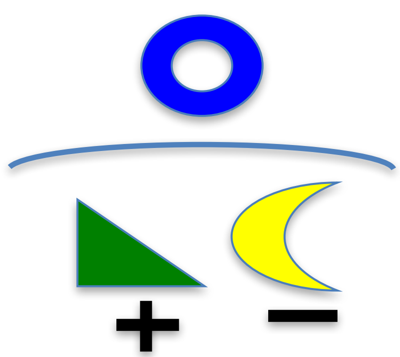
Dolphins (like Apes) can reach
First Trial Success,
with novel auditory or
(appropriate) visual stimuli

(although no data on
transfer between
problem types)

Can also learn
<u>CMTS</u>

(although no data on
transfer between
problem types)

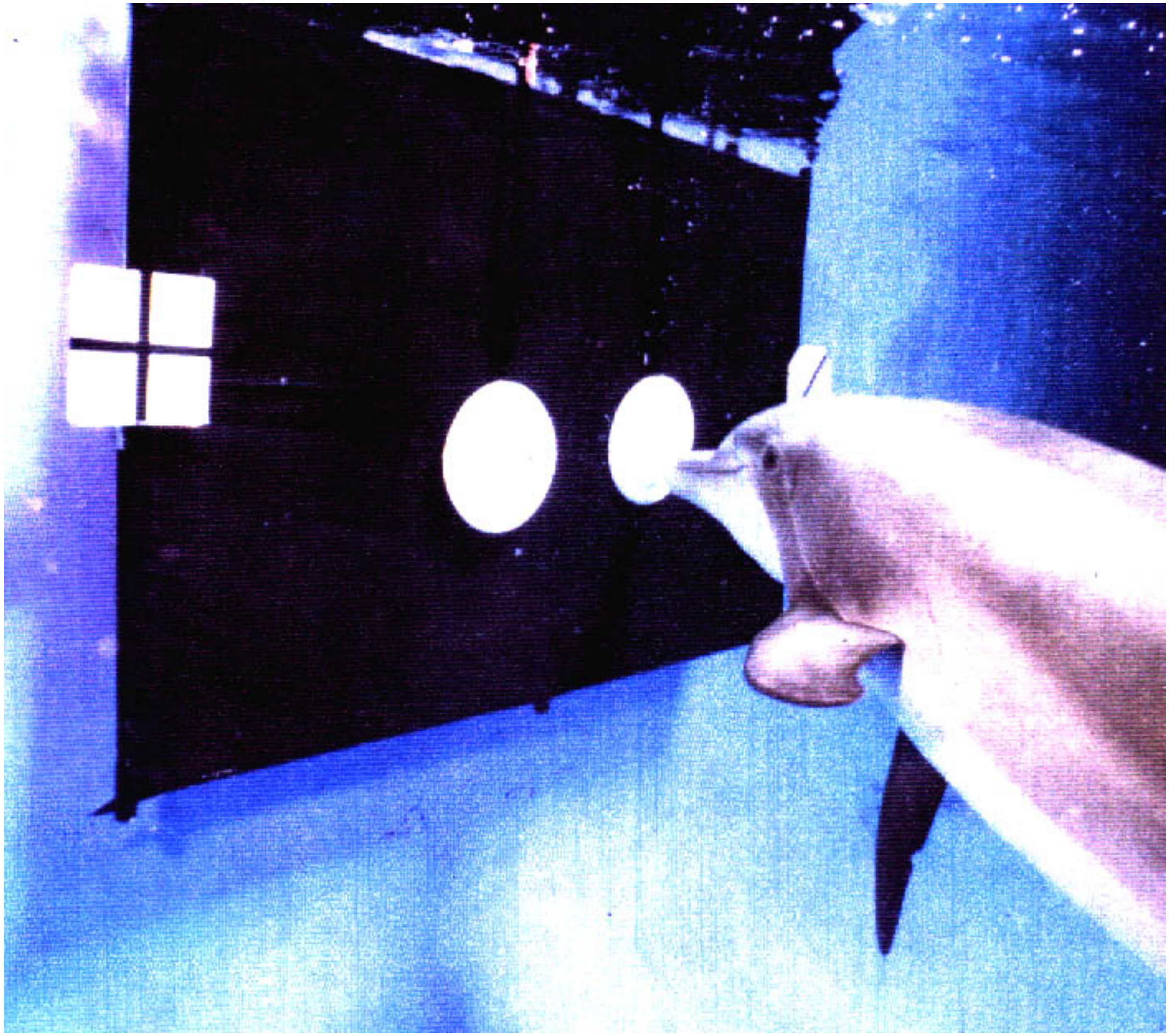
“Conditional”
(“Symbolic”) MTS



Subjects cannot
show “first trial success”
on CMTS,
since must receive reward to
determine “correct” alternative

But do show “<u>One Trial Learning</u>”
with NOVEL stimuli

Same / Different



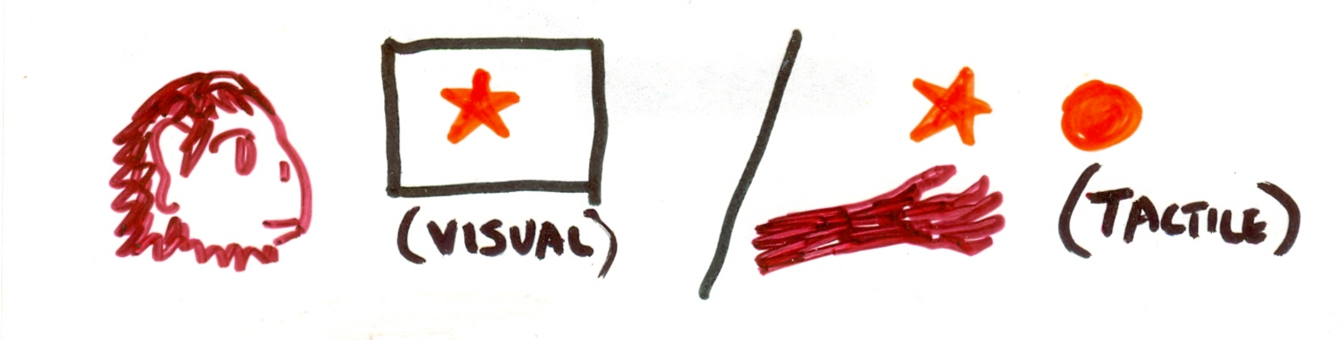
More difficult for subjects than MTS

Perhaps because assess objects, but <u>respond</u> to other stimuli (i.e. + & - paddles)?

Dolphins were able to reach criterion with novel objects

Cross-Modal Matching

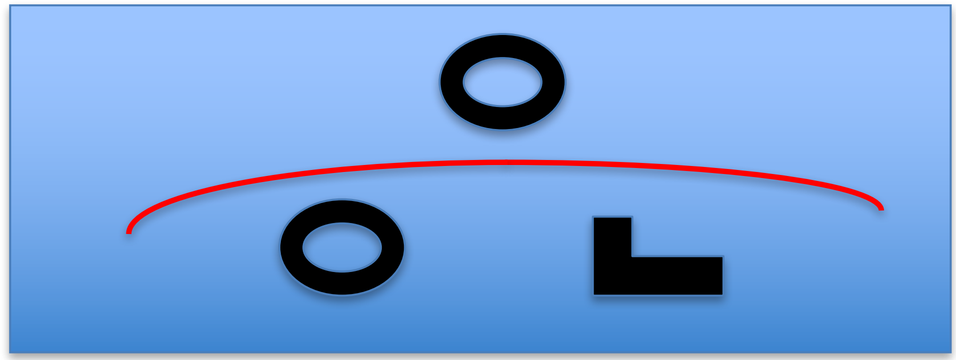
Primates best at Visual / Tactile



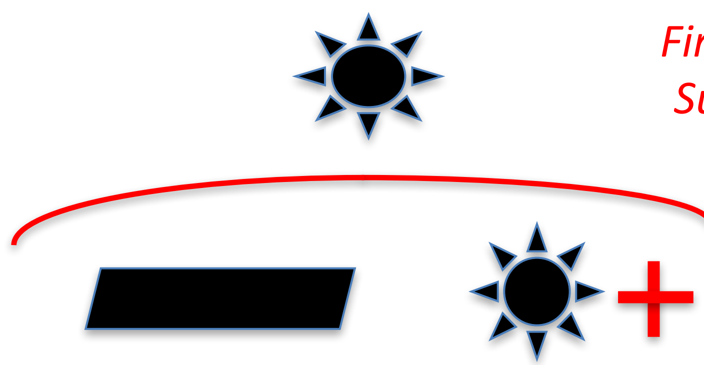
Dolphins best at Visual / Auditory

Cross-Modal Matching

Dolphins also excel at transferring MTS learned acoustically, to MTS visually.



Trained in auditory mode, underwater



First Trial Success!

Tested in visual mode, in air

Primates poor at transferring MTS learning in one modality to new test in other modality