Letter identification: Evidence for scale dependence but not for fixed channels

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A special mechanism for letters?

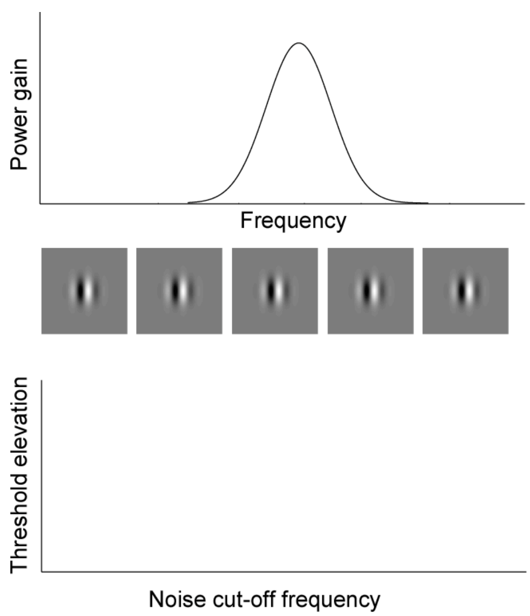
1. Letter channels
2. Scale dependence
3. Lack of channel switching

Solomon & Pelli (1994)
Majaj et al. (2002)

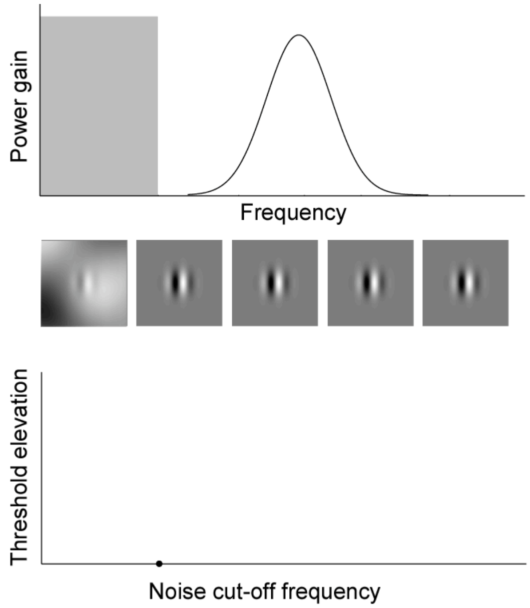
1. Letter channels

- All bands contain diagnostic information
- Efficiencies are approximately equal for all bands (Parish & Sperling, 1991; Gold, Bennett & Sekuler, 1999).
- Nevertheless, Solomon & Pelli (1994), and Majaj et al. (2002) find human observers use a narrow band when identifying letters using the critical-band masking paradigm.

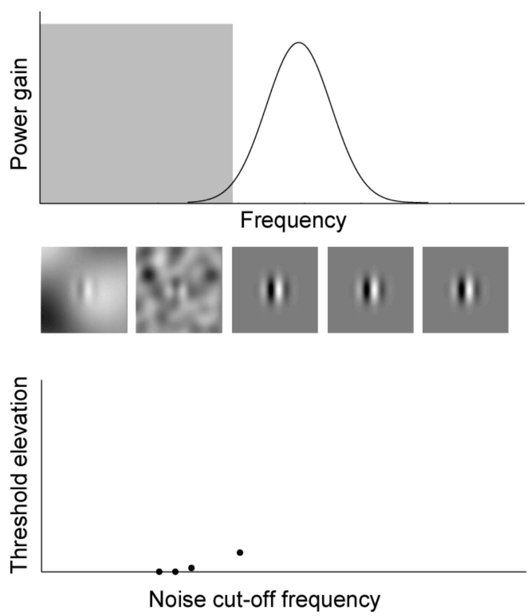
Critical-band masking



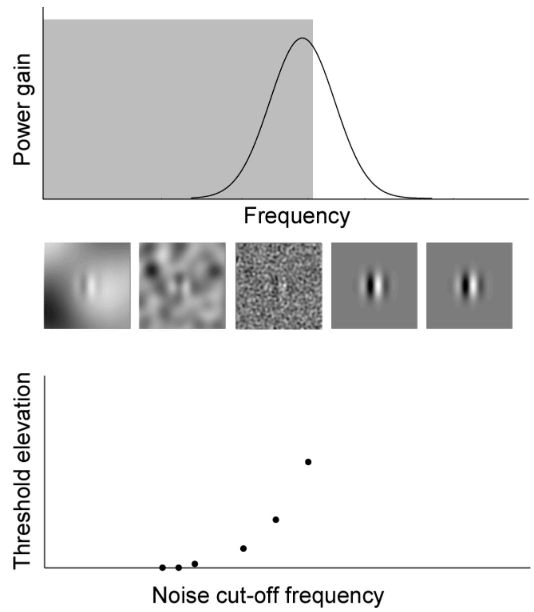
Critical-band masking



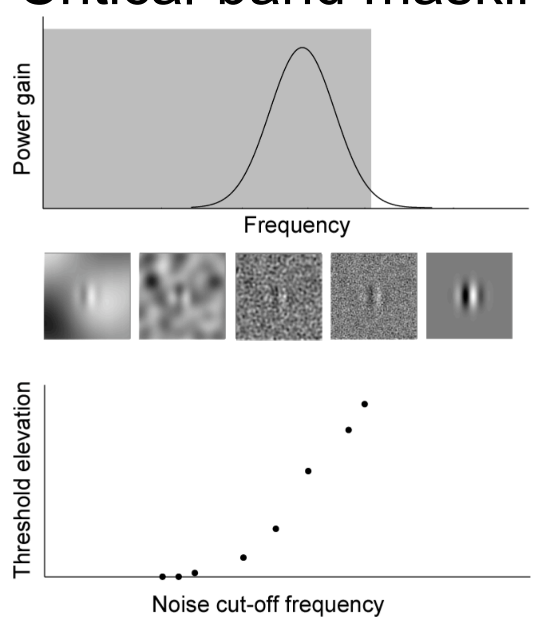
Critical-band masking



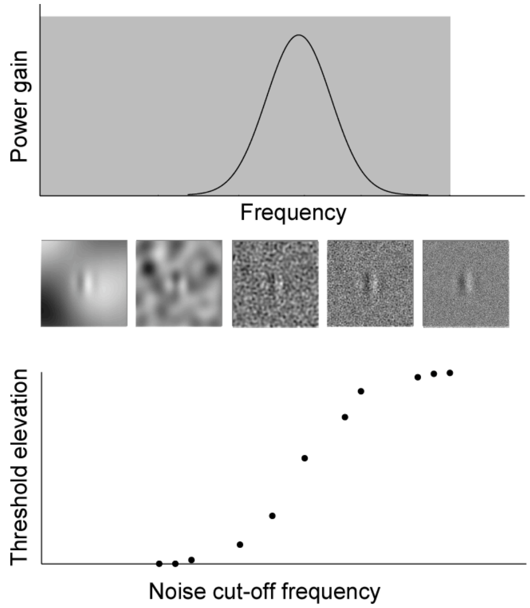
Critical-band masking



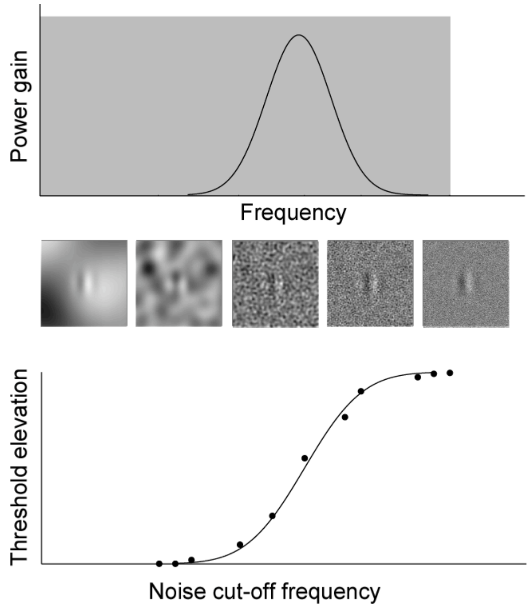
Critical-band masking



Critical-band masking

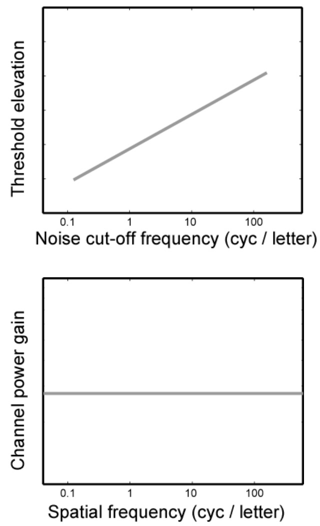


Critical-band masking



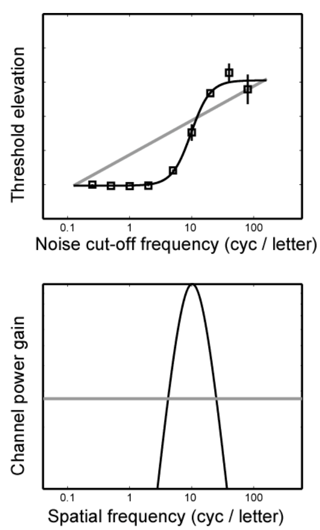
Letter channels

If all parts of the spectrum are useful *and* used equally



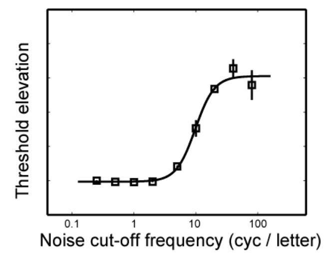
Letter channels

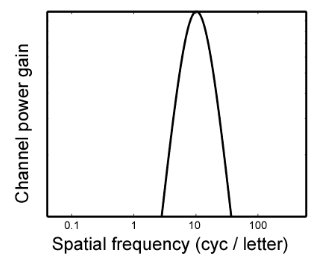
Actual data



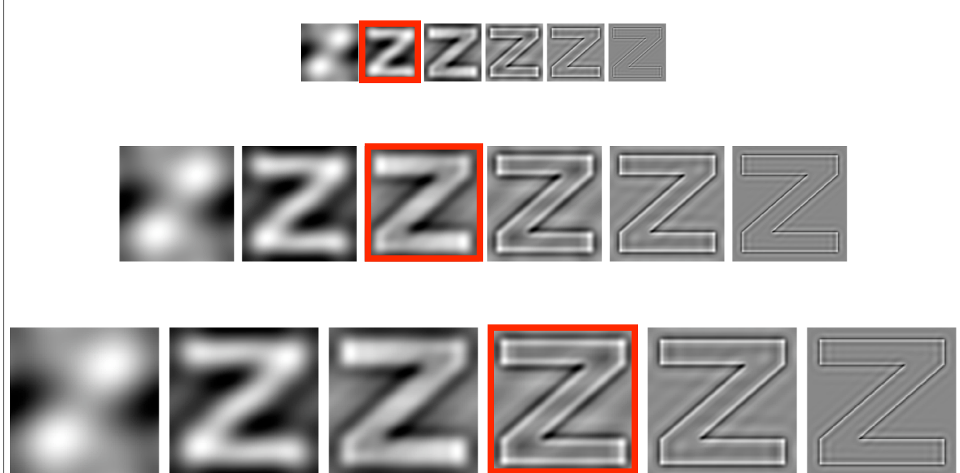
Letter channels

Actual data

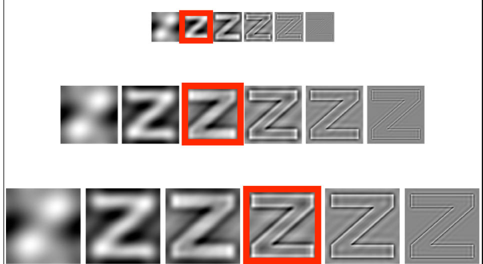




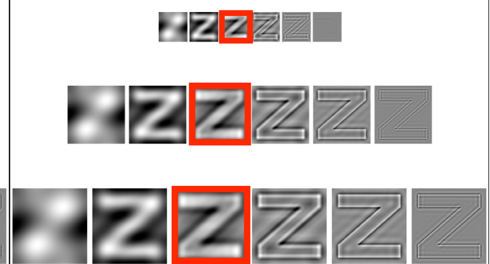
2. Scale dependence



Scale dependence



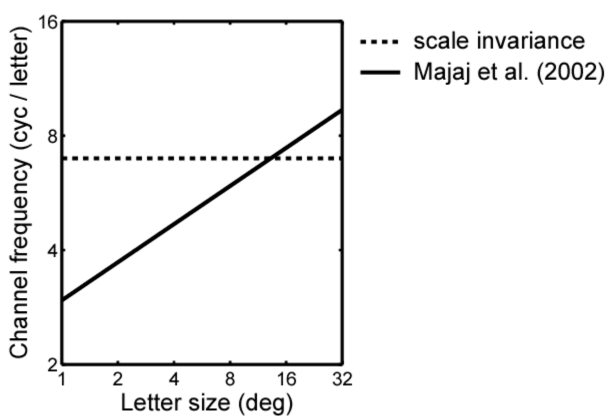
Actual data: scale dependent



Ideal observer: scale invariant

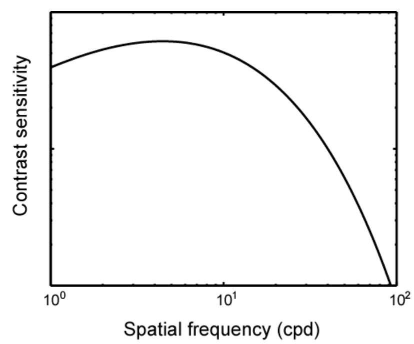
An ideal observer would act the same way at all sizes

Scale dependence



Why scale dependence?

- Human's are not equally sensitive to all frequencies
- Perhaps this forces subjects to switch their channels toward areas of the spectrum to which they are more sensitive, defeating scale invariance.



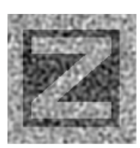
Chung, Legge & Tjan, 2002, Ojanpää & Näsänen, 1999, Oruc, Landy & Pelli, 2006

Scale dependence

EXPERIMENT 1

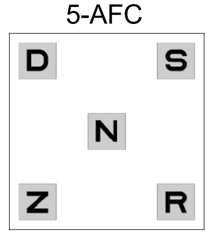
Letter discrimination with critical-band masking

Brief stimulus



150 ms

5-AFC



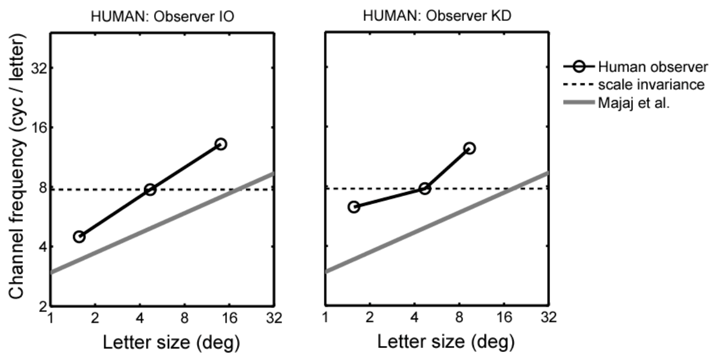
Repeat for three sizes

z Z Z

Scale dependence

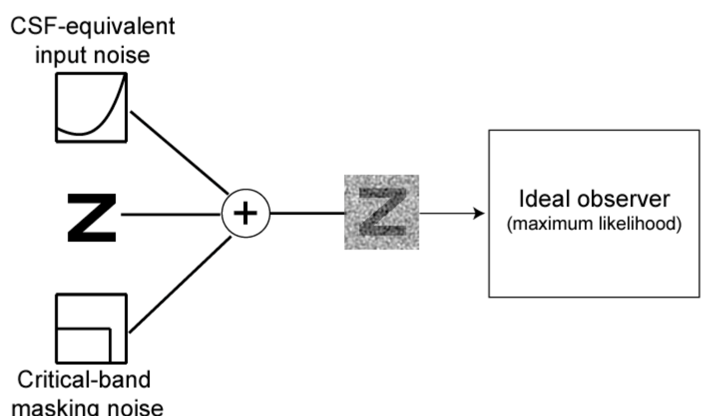
EXPERIMENT 1
Results: Human

Replicate Majaj et al.



Scale dependence

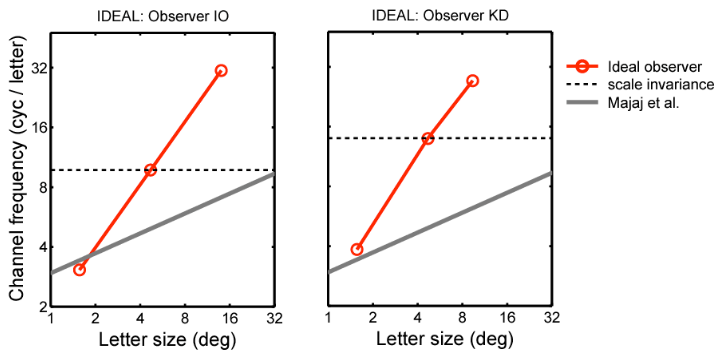
Ideal observer with a human CSF



Ahumada & Watson (1985)

Scale dependence

EXPERIMENT 1
Results: Ideal



Scale dependence

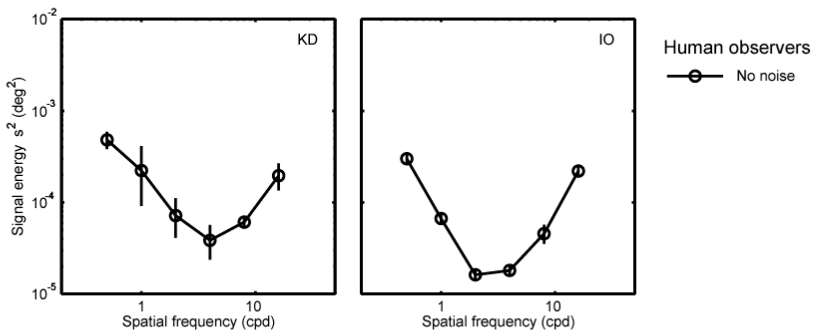
SUMMARY
Experiment 1

- **We replicate the finding of scale-dependence.**
- …**but an ideal-observer hampered by CSF-equivalent input noise is also scale-dependent.**
- **Reverse the argument**: if CSF were flattened, humans should become scale invariant.

Scale dependence

EXPERIMENT 2

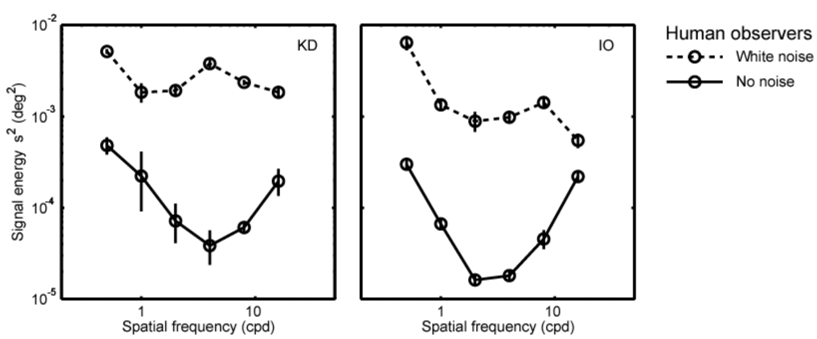
Add white noise to flatten the CSF



Scale dependence

EXPERIMENT 2

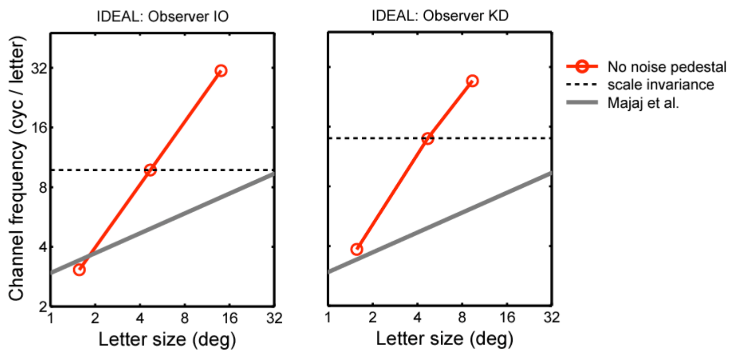
Add white noise to flatten the CSF



Scale dependence

EXPERIMENT 2
Results: Ideal

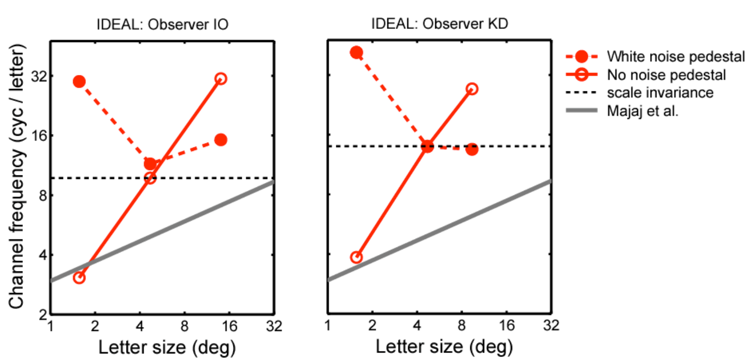
Predict

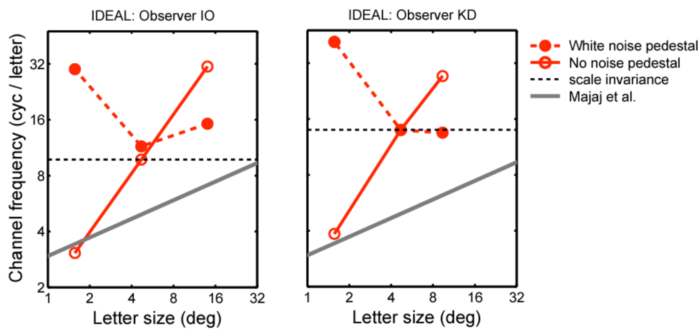


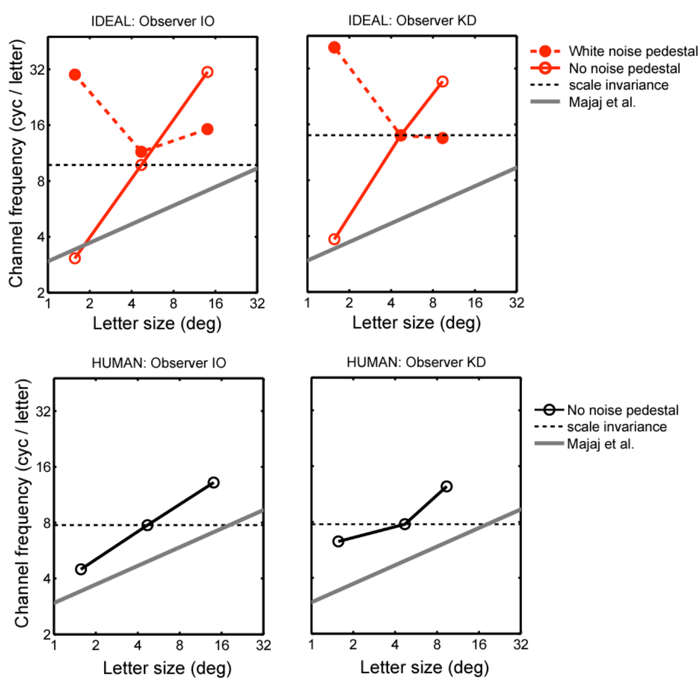
Scale dependence

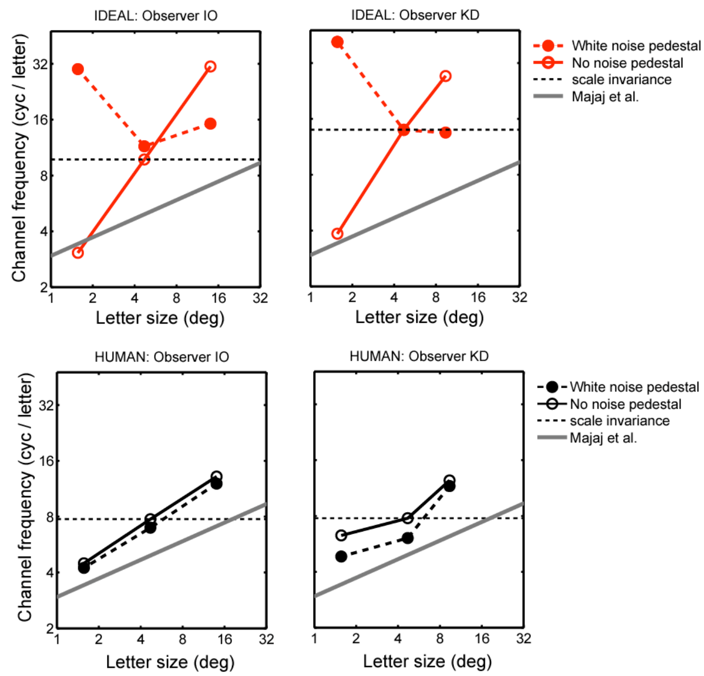
EXPERIMENT 2
Results: Ideal

Predict




IDEAL: Observer IO
IDEAL: Observer KD
Channel frequency (cyc / letter)
Letter size (deg)
White noise pedestal
No noise pedestal
scale invariance
Majaj et al.


IDEAL: Observer IO
IDEAL: Observer KD
HUMAN: Observer IO
HUMAN: Observer KD
Channel frequency (cyc / letter)
Letter size (deg)
White noise pedestal
No noise pedestal
scale invariance
Majaj et al.



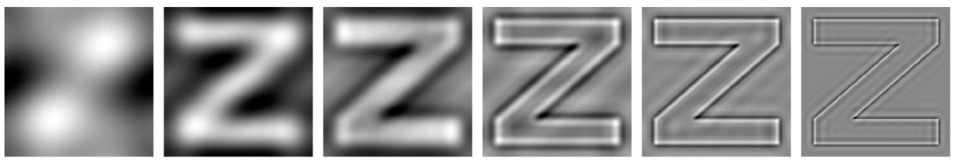
Scale dependence

SUMMARY
Experiment 1 & 2

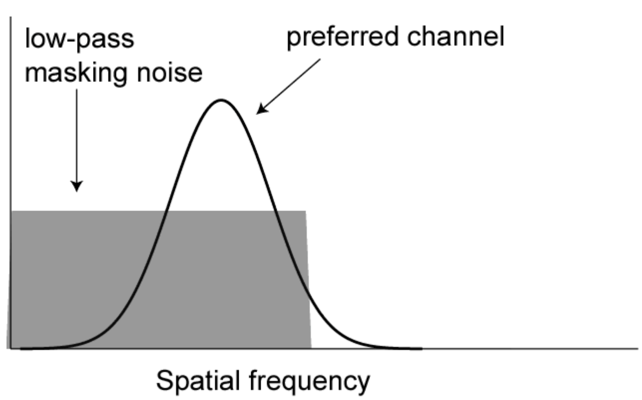
• **CSF explains scale dependence**: When the ideal observer is hampered by CSF-equivalent input noise, it becomes scale-dependent like the human observers.

•…but **it does not predict scale dependence**: Human observers, unlike the ideal, continue to behave in a scale-dependent manner with a white noise pedestal, even though this should degrade performance.

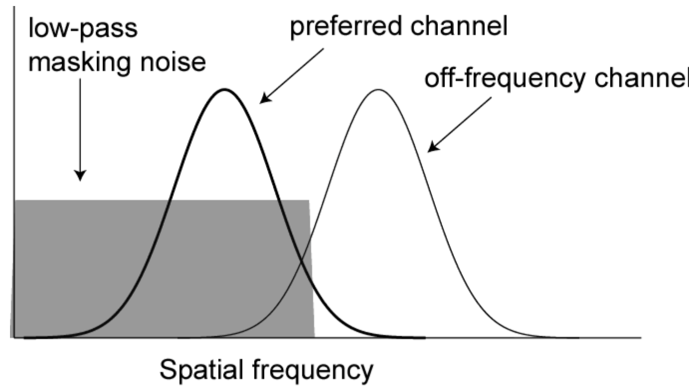
3. Channel switching



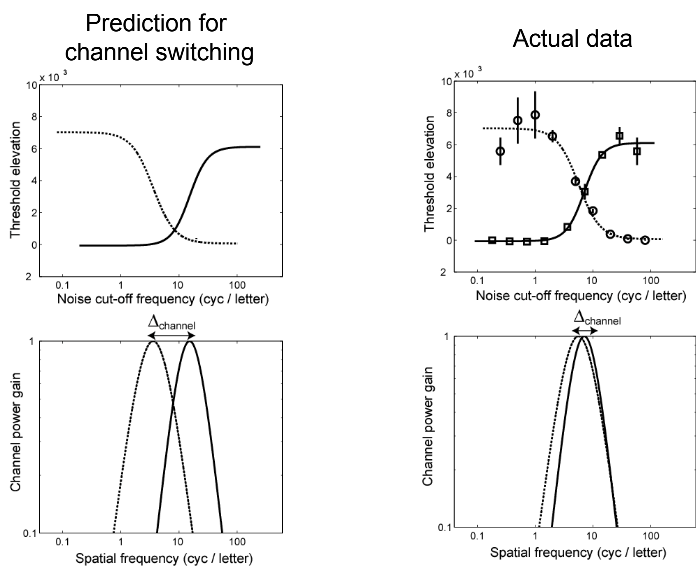
Channel switching



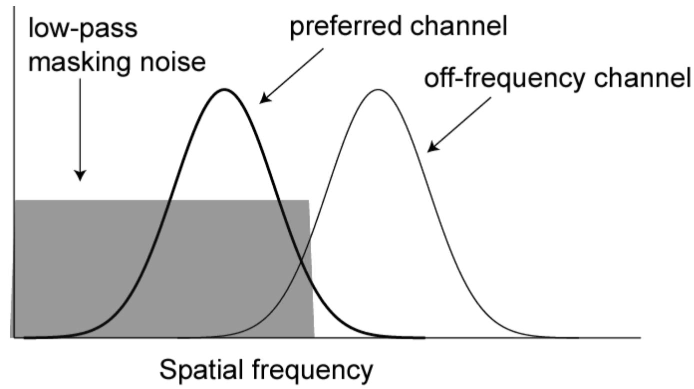
Channel switching



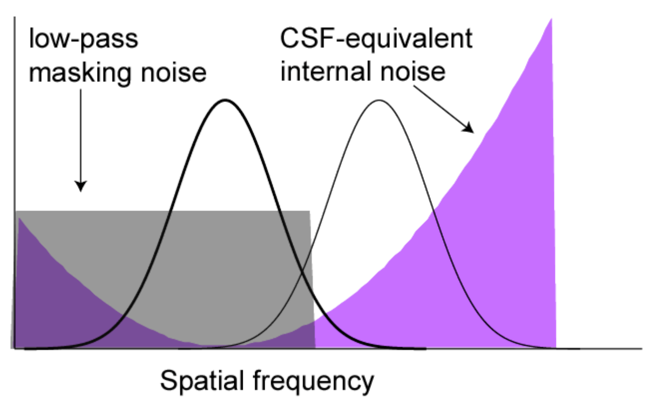
Channel switching



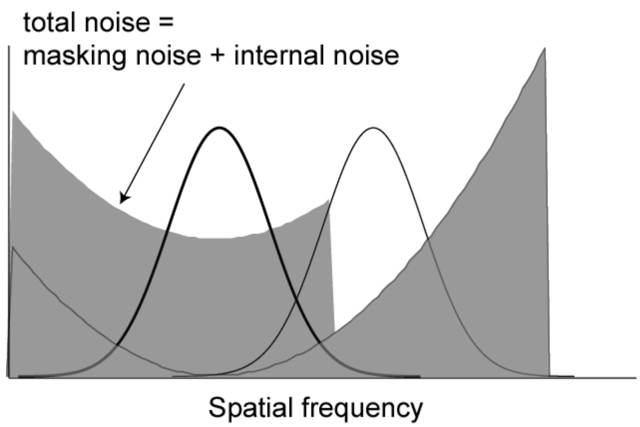
Channel switching



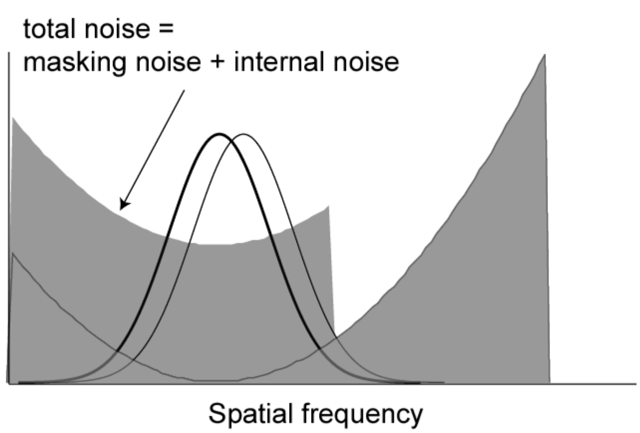
Channel switching



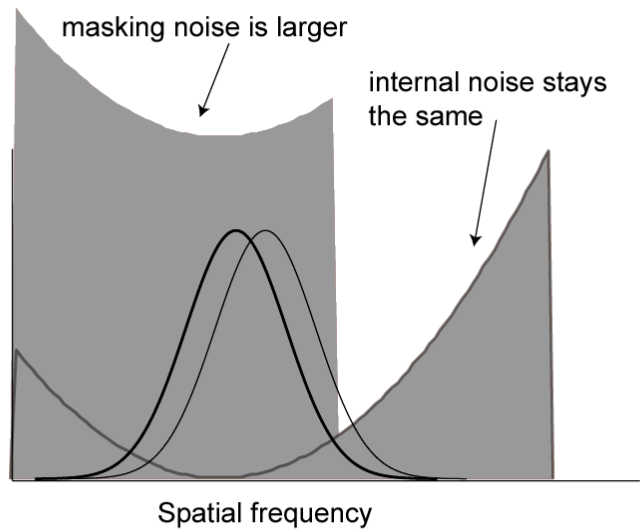
Channel switching



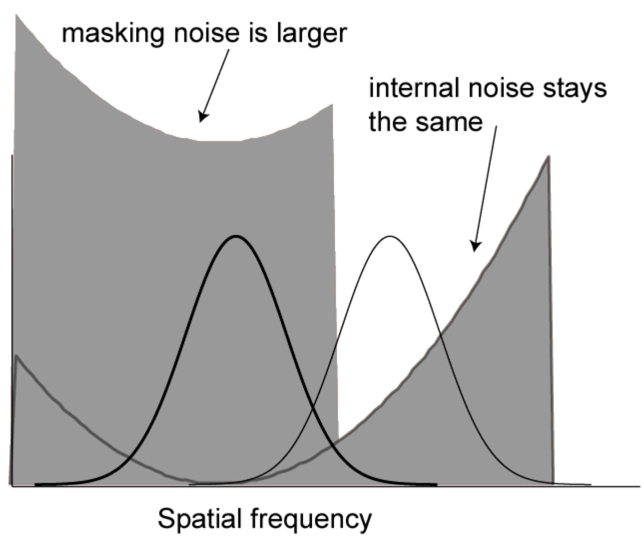
Channel switching



Channel switching



Channel switching

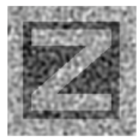


Channel switching

EXPERIMENT 3

Letter discrimination with critical-band masking

Brief stimulus

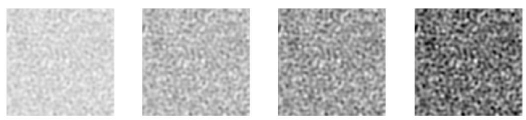


150 ms

5-AFC

D S
N
Z R

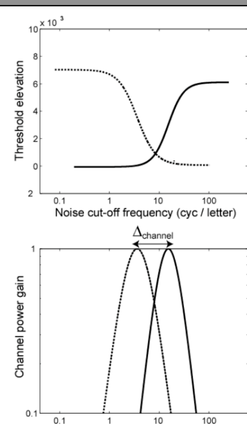
4 levels of masking noise



20% 40% 60% 80%

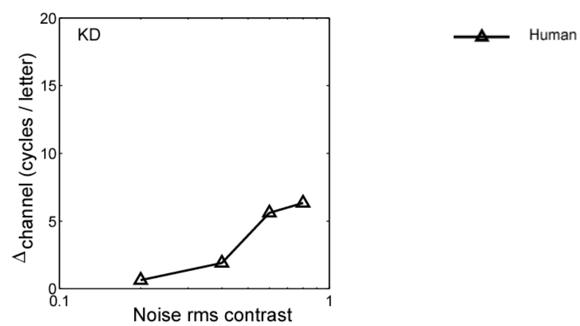
Channel switching

EXPERIMENT 3: Data analysis



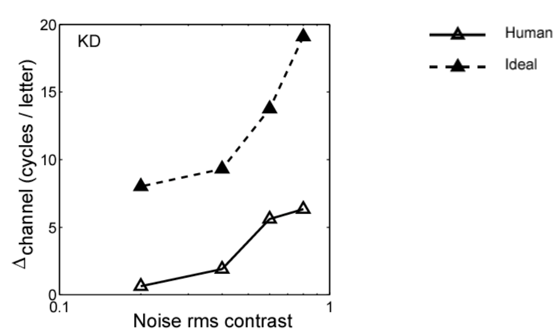
Channel switching

EXPERIMENT 3:
Results

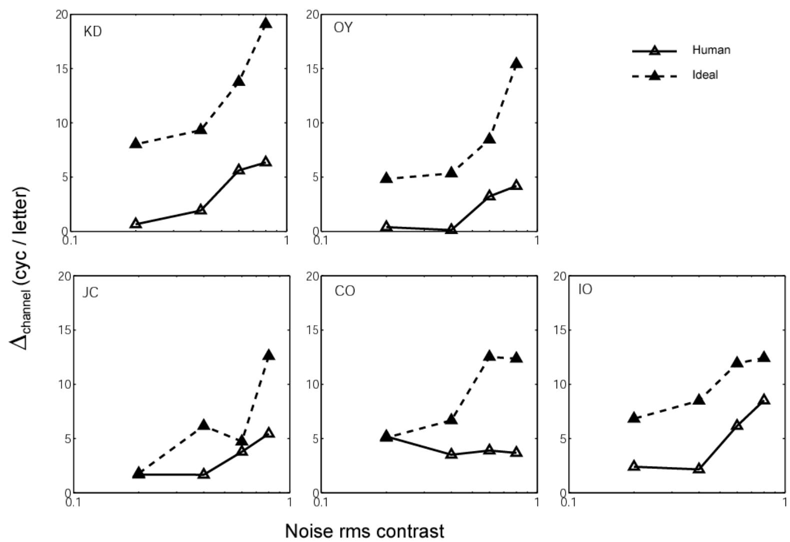


Channel switching

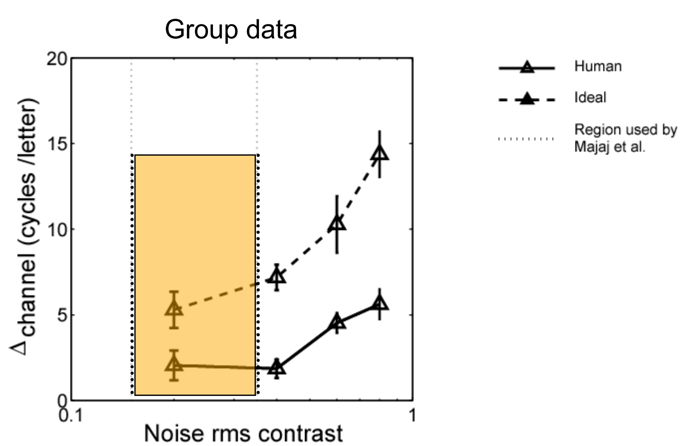
EXPERIMENT 3:
Results



Channel switching



Channel switching



Channel switching

SUMMARY
Experiment 3

• **We DO see channel switching** if the noise is strong enough, and Majaj et al. used noise that was too weak.

Conclusions

- Humans are not fixed in the letter channel they use: they do switch channels when it improves SNR.
- Scale dependence is due to the band-pass shape of the CSF, but it is a long-term adaptation.
- A combination of two types of constraints explains most of the results: The letter diagnostic information across the spectrum and total noise spectrum.
- The finding of “letter channels” is not surprising; the ideal observer shows the same behaviour.

Acknowledgements

- CO, JC and OY for participating
- Alan Kingstone & Walter Bischof for support
- Denis Pelli for discussion