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

Ipek Oruc\textsuperscript{1} 
Michael S. Landy\textsuperscript{2}

\textsuperscript{1} University of British Columbia  
\textsuperscript{2} New York University

\textbf{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

- Power gain
- Frequency
- Threshold elevation
- Noise cut-off frequency
Critical-band masking

![Power gain vs Frequency](chart1.png)

Threshold elevation vs Noise cut-off frequency

![Threshold elevation](chart2.png)
Critical-band masking

Power gain

Frequency

Threshold elevation

Noise cut-off frequency
Letter channels

If all parts of the spectrum are useful and used equally

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Actual data

Threshold elevation

Noise cut-off frequency (cyc / letter)

Channel power gain

Spatial frequency (cyc / letter)
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2. Scale dependence
An ideal observer would act the same way at all sizes.
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.


Scale dependence

**EXPERIMENT 1**

Letter discrimination with critical-band masking

Brief stimulus 5-AFC

150 ms

Repeat for three sizes
Scale dependence

**EXPERIMENT 1**

Results: Human

Replicate Majaj et al.

![Graphs showing scale dependence for human observers](image)

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Scale dependence

Ideal observer with a human CSF

![Diagram showing ideal observer model](image)

Ahumada & Watson (1985)
Scale dependence

EXPERIMENT 1
Results: Ideal

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

Human observers

- No noise

Scale dependence

EXPERIMENT 2

Add white noise to flatten the CSF

Human observers

- White noise
- No noise
Scale dependence

**EXPERIMENT 2**

Results: Ideal

Predict

![Graphs showing scale dependence results](image)
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

low-pass masking noise
preferred channel

Spatial frequency
Channel switching

Prediction for channel switching

Actual data
Channel switching

low-pass masking noise
preferred channel
off-frequency channel
Spatial frequency

Channel switching

low-pass masking noise
CSF-equivalent internal noise
Spatial frequency
Channel switching

Total noise = masking noise + internal noise

Spatial frequency
Channel switching

- Masking noise is larger
- Internal noise stays the same

Spatial frequency
Channel switching

EXPERIMENT 3
Letter discrimination with critical-band masking

Brief stimulus

5-AFC

150 ms

4 levels of masking noise

20% 40% 60% 80%

Channel switching

EXPERIMENT 3:
Data analysis

Threshold elevation

Noise cut-off frequency (cyc/letter)

Spatial frequency (cyc/letter)

Channel power gain
Channel switching

EXPERIMENT 3: Results

![Graph showing channel switching results]

Channel switching

EXPERIMENT 3: Results

![Graph showing channel switching results with Human and Ideal lines]

Noise rms contrast vs. Δ-channel (cycles/letter)

KD
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