# Templates are in the Eye of the Beholder

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**#E59**

## INTRODUCTION

When given a pattern detection task, an analysis of the subjects' internal templates or classification images reveals a significant difference between signal present and signal absent conditions. The stimulus and noise in this experiment were designed to allow a reconstruction of the subject's internal template through a linear regression analysis of the weighting of sensitivity to each frequency component. Because subjects don't know if the signal will be present or not, they should always be looking for the same target pattern. This predicts that the internal template should be nearly identical regardless of signal presence or absence. We analyzed the subjects efficiency and consistency of response, and found an apparent contradiction.

## METHODS

Four combinations of two cosine gratings, the 2nd and 6th harmonics of a 0.5 c/deg grating (1 c/deg and 3 c/deg respectively), were used as the target stimulus patterns. Pattern 1 is the 2nd harmonic in isolation, pattern 2 is the 6th harmonic in isolation, pattern 3 is the 2nd plus the 6th and pattern 4 is the 2nd minus the 6th. The one-dimensional noise was the sum of 1st-7th harmonics of a 0.5c/deg fundamental. The contrast of each noise harmonic n and m were generated randomly and had a mean of zero and had a 4% Gaussian standard deviation in both sine and cosine phases. The one-dimensional stimulus was:

$$\text{Stim}(x) = c_2*\cos(2fx) + c_6*\cos(6fx) + \Sigma_{j=1\text{ to }7}\,(n_j\,(\cos(jfx) + m_j\,(\sin(jfx))$$

| ENVELOPES | PROFILE | SAMPLE STIMULI | PROFILE W/ NOISE | SAMPLE STIMULI W/ NOISE |
|---|---|---|---|---|
| **1) 2nd HARMONIC** ($c_2$=1, $c_6$=0) | | | | |
| **2) 6th HARMONIC** ($c_2$=0, $c_6$=1) | | | | |
| **3) 2nd + 6th** ($c_2$=1, $c_6$=1) | | | | |
| **4) 2nd – 6th** ($c_2$=1, $c_6$=-1) | | | | |

The stimulus was presented for a short duration (0.5 or 0.75 sec depending on subject). A small white mark was presented to the side of each stimuli at its midpoint to assist subjects in centering their template. Observers were able to refresh their memory of the appearance of the zero noise template while in the middle of a run. Stimuli were displayed using WinVis (Neurometrics Institute) for Matlab (The MathWorks, Inc)

We used the method of constant stimuli with 4 test contrasts (first level was 0 or no signal) and 4 responses. We used five subjects, two experienced in psychophysical experiments and three naive. Auditory feedback based on the ideal observer's response rather than the pre-noise stimulus was given after each trial to help subjects refine their template and their response criterion. There were 200 trials per run and 2-3 runs were performed by each subject using identical random seeds each time to allow for subsequent doublepass analysis.

For each envelope and each subject, the following items were calculated:

i) Pictures of the subject's internal Templates were recovered from the coefficients of the subject's weights for each frequency. The higher the coefficient, the more sensitive the subject was to strength in that frequency.

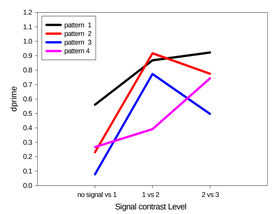
ii) Each subject's dprime was calculated between the signal absent condition and the lowest contrast signal present condition, and between the subsequent levels of increasing contrast.

iii) The Template Efficiency, was calculated by comparing the subject's templates to the template obtained by an ideal observer. The ideal observer differed from the ideal template because of the external noise.

iv) The subject's internal consistency was calculated by examining the response correlation between each pass through the same stimuli set.

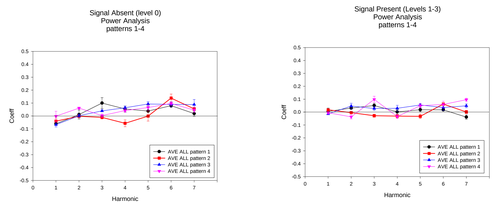
v) The power coefficients for each subject were calculated by regressing the subjects' responses on the noise power $n_j^2 + m_j^2$

## D prime




**Results: Dprimes were lowest between the signal absent and signal present conditions for all patterns. The dprimes were generally highest for simpler patterns 1 and 2 but not by a large amount.**

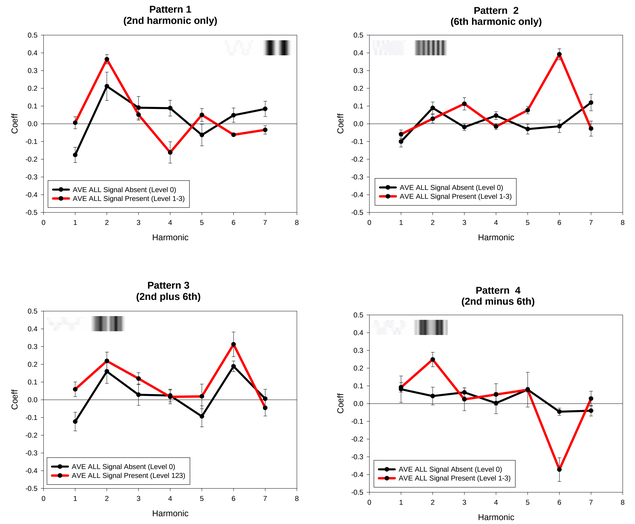
## Power Analysis




**Results: Overall the power analysis was flat over all frequencies which implies that subjects were not using power significantly. However for all patterns in the signal absent conditions, there was a significant elevation in the 6th harmonic. For pattern 4 there was also an elevation in the second harmonic in the signal present condition.**

## Subject's Templates

**NOTE**: **error bars** represent the standard error of the mean of the data.



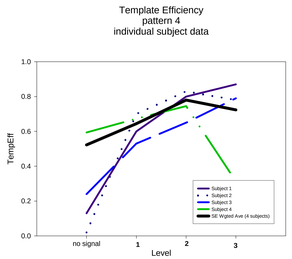

**Results: Patterns 1 and 3 show the subject's template for the signal absent condition was noisy but similar to the signal present conditions while there was no such template for patterns 2 and 4 when there was no signal.**

## Template Efficiency and Correlation

| | | No Stimulus | | Stimulus Level 1 | | Stimulus Level 2 | | Stimulus Level 3 | | TTEST | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Weighted Ave | SE | Weighted Ave | SE | Weighted Ave | SE | Weighted Ave | SE | 1 vs 2 | 2 vs 3 | 3 vs 4 |
| Temp Eff | Pattern 1 | 0.39 | 0.10 | 0.76 | 0.02 | 0.74 | 0.05 | 0.75 | 0.06 | 0.01 | 0.94 | 0.88 |
| | Pattern 2 | 0.14 | 0.16 | 0.86 | 0.08 | 0.85 | 0.03 | 0.76 | 0.04 | 0.00 | 0.30 | 0.05 |
| | Pattern 3 | 0.34 | 0.11 | 0.54 | 0.06 | 0.67 | 0.05 | 0.58 | 0.05 | 0.61 | 0.05 | 0.66 |
| | Pattern 4 | 0.13/0.68* | 0.6/0.8* | 0.64 | 0.03 | 0.78 | 0.03 | 0.72 | 0.11 | 0.05/0.28* | 0.01 | 0.32 |

* see Results  * see Results

| | | No Stimulus | | Stimulus Level 1 | | Stimulus Level 2 | | Stimulus Level 3 | | TTEST | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Weighted Ave | SE | Weighted Ave | SE | Weighted Ave | SE | Weighted Ave | SE | 1 vs 2 | 2 vs 3 | 3 vs 4 |
| Correlation | Pattern 1 | 0.34 | 0.07 | 0.41 | 0.09 | 0.45 | 0.08 | 0.45 | 0.07 | 0.20 | 0.41 | 0.96 |
| | Pattern 2 | 0.40 | 0.04 | 0.42 | 0.09 | 0.57 | 0.05 | 0.38 | 0.06 | 0.78 | 0.03 | 0.08 |
| | Pattern 3 | 0.38 | 0.07 | 0.36 | 0.06 | 0.50 | 0.07 | 0.37 | 0.06 | 0.50 | 0.06 | 0.20 |
| | Pattern 4 | 0.36 | 0.05 | 0.51 | 0.07 | 0.44 | 0.07 | 0.36 | 0.08 | 0.15 | 0.48 | 0.52 |




**Results: For Template Efficiency, significant T-tests between the signal absent and signal present conditions on all but pattern 3. Correlations were steady and not significantly different no matter the pattern or stimulus level except in one condition (noted in red).**

**Pattern 4 was analyzed slightly differently when it became clear that one subject (#4) had significantly different results for Temp Eff than the other subjects and skewed the weighted average results. See graph to the left. Their data was separated out. The first number in the chart above is the weighted average of the subjects *not including Subject 4*, and the second number is Subject 4's data alone. Note: the fifth subject's data was corrupted and not included for this pattern only.**

## HYPOTHESES

***Bad Fixation***
***What this means:*** Subjects do not use fixation point properly or are unable to see it well enough to use it to center their templates. The subject's templates "jitter" randomly in relation to the fixation point from trial to trial.
***If this were true we would find:*** Correlation and consistency: medium Template efficiency (quality of template): medium to low at high frequency stimuli, high at low frequencies, degraded at high frequencies (harder to center). Should find some increase in efficiency with contrast because of assistance of pedestal in centering template.
***Supported or not?:*** **Supported**, we did find efficiency changed as the stimulus increased in contrast and frequency. Efficiency was lowest in signal absent conditions (no pedestal) and at the 3 c/deg stimulus (harder to center because of finer detail, harder to differentiate from neighboring frequencies). Correlation was ~40-50% and fairly constant over all envelopes and stimulus conditions. The correlation was high even for the 3 c/deg blank stimulus since a pattern that looked like a shifted 3 c/deg stimulus would get a high rating, consistent across runs. See next hypothesis for further validation.

***Some Other Cue/Power/Single Channel***
***What this means:*** Subjects are using another cue, such as power to make determination about signal presence and strength
***If this were true we would find:*** significant responses in the power component of the coefficients of the template
***Supported or not?:*** **Partially Supported**, significant responses only found for 3 c/deg frequency blank (signal absent) stimuli, implying that power may be used to assist ability to detect high frequency stimuli in zero pedestal (signal absent) case.

***Mismatched Template***
***What this means:*** Subjects use a single template for all patterns, but it is the wrong one
***If this were true we would find:*** Two-pass correlation (consistency): High for correct template, lower for mismatched stimuli. Template efficiency: High for correct template, lower for mismatched stimuli
***Supported or not?:*** **Unsupported**, analysis of subjects templates show that they use different templates for the different stimuli

***Multiple Templates/Multiple Channels***
***What this means:*** Subject uses multiple templates depending on either signal strength or some other criteria. Perhaps they pay attention to "channel" with greatest strength, the signal and noise "guiding" the template.
***If this were true we would find:*** Correlation and consistency would be medium to high, each time they should respond to the stimuli+noise the same no matter if they were correct or incorrect. Efficiency should increase with signal level (increasing strength of signal in appropriate channel).
***Supported or not?:*** **Unsupported**, When signal was present, efficiency did not increase significantly as signal contrast increased. Correlation was consistent from envelope to envelope, and the efficiency did vary from envelope to envelope, but this seemed to correlate more with the frequencies present rather than the total contrast of the noise and stimuli.

## SUMMARY & DISCUSSION

The subject's Templates revealed that each subject could form a template that matched the target pattern but f[illegible] 2 ([illegible] 4 ([illegible]), they had difficulty forming any template in the signal absent conditions. The Template Efficiencies showed a huge increase between target absent and target present conditions but was relatively constant across all three stimulus present contrast levels. The correlation and consistency for each subjects was approximately 0.45, independent of the stimulus level or target pattern.

The initial results seemed to contradict each other: In the signal absent conditions, the template efficiency drops significantly (from ~70% efficiency to ~30%). The low d-primes from signal absent to signal present underlined the difficulty subjects had in discriminating between the two situations. However the correlation was relatively high and consistent independent of stimulus level. The surprising implication from our double-p[illegible]ments is t[illegible]ismatches or mistakes are done consistently. Patterns 2 and 4 had a near zero template in the signal absent conditions, unlike Patterns 1 ([illegible]) and 3 ([illegible]), where the signal absent template was similar to the signal present template.

The classification images revealed that the subjects were able to create reasonably correct templates particularly for the lower frequency harmonics (1 c/deg), where precise template alignment was less critical. However at the higher frequency (3 c/deg) the behavior became more variable depending on how successful the subject's strategy was for coping with the more difficult detection tas[illegible]e of its misalignment sensitivity, P[illegible]s much more difficult at low contrast and signal absent conditions. Even though Pattern 4 ([illegible]) has low frequency information like Pattern 3 ([illegible]), one of the critical features is a small dark bar at the center, which can be easily misaligned and confused with a dark bar due to noise in the 5th or 7th harmonic, creating a situation just like Pattern 2.

Clearly some patterns were harder to detect than others. In the case of Pattern 4, only one subject, was able to form a successful template. By separating out that subject's data, it was clear that the other subjects did not adapt a similar strategy. This could be a fifth hypothesis: the "Clever Template". If the subjects find a strategy that works extremely well, they can overcome some of the difficulties presented by the higher frequencies. The subject reported that they adopted a two step decision process- first, was the lower frequency fundamental present with two dark bars? If so, was there also a small dark bar at or very close to the fixation point? This created a template very similar to the desired target even if they ignored the other details such as the lighter bars in the middle of the wide dark bars, or the two light bars on either side of the fixation point.