The Impacts of Visual Adaptation on Stimulus Salience

A thesis submitted in partial fulfillment
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Abstract

Adaptation is defined as becoming desensitized to a stimulus due to repeated exposure to that stimulus. All sensory systems rapidly adapt their sensitivity in response to changes in the stimuli they are exposed to. However, the exact function of adaptation remains unclear. This study examined the hypothesis that adaptation serves to highlight the perception of new information in the environment, by reducing sensitivity to the prevailing stimulus. This was tested by examining how adaptation changes the relative salience of information in hybrid images. A hybrid image is a mixture of two different images, one image that is low-pass filtered to remove fine details to appear blurry, and the other that is high-pass filtered to remove the blur and preserve only the fine details to appear sharpened. Which image is perceived by the observer depends on the viewing distance and on the relative contrast or strength of the two images. This study utilized a hybrid image composed of the faces of celebrities George Clooney and Brad Pitt to determine whether the image perceived also depends on the adapted state of the observer by **testing whether the relative salience of the two images is altered by prior exposure to one of the component images**. In addition, the study tested which aspect of the stimulus controls the adaptation: **the identity of the image itself or the amount of blur in the image**. The results of the study suggest that adaptation to the identity biased the perceived identity despite differences in the blur, while adaptation to the blur level biased the perceived level of blur regardless of identity. These results are consistent with the hypothesis that adaptation acts to increase the salience of more novel stimuli, and suggest that different attributes adapt independently.
Acknowledgements

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Introduction

Visual perception must operate efficiently across large changes in the environment or the observer. For example, the light environment cycles between night and day, and changes in color or form with changes in the seasons or ecosystem. Observers in the same environment can also differ greatly in the properties of their visual system. For example, individuals vary in the shape of the cornea and lens in their eyes, leading to very different patterns of the level of blur in their eyes. However, despite this blur in the retinal image, the world itself often does not appear blurred. This perceptual consistency is potentially due to processes of adaptation that correct visual coding for the sensitivity limits of the observer (Webster et al, 2002).

Adaptation is a prominent process that is defined as a decreased response to a specific stimulus in the environment resulting from repeated exposure to that stimulus (Ranganath & Rainer, 2003). This decreased response is thought to be due to the neurons in the brain becoming habituated to stimuli already present in the environment, and responding to these types of stimuli with less intensity than when presented with novel stimuli (Ranganath & Rainer, 2003). In the same way, the visual system may be adapting to the characteristics of the observer-such as the blur in his or her eyes - by becoming desensitized to the normal amount of blur the he or she experiences. Because the visual system constantly adapts to this blur, therefore matching sensitivity and perception for the physical environment (Dong et al, 2016, Souto et al, 2016), the world does not appear blurred. These adjustments affect all aspects of visual perception, and thus can have a large effect on everything we see. For example, adaptation also occurs for faces, so that
after viewing one kind of face (e.g. a particular age or gender) subsequent faces look less like the adapting face (Webster et al, 2004).

Although adaptation is known to have a powerful and rapid effect on perception, the reasons for these sensitivity changes are still poorly understood. One hypothesis regarding the role of adaptation is that it functions to highlight new stimuli in the environment through desensitizing an individual to the stimuli already present in the environment (McDermott et al, 2010). This study examined this hypothesis by measuring the effects of adaptation on hybrid images.

A hybrid image is formed by combining two images filtered at different spatial scales such as the image depicted in Figure 1.

\[ \text{Figure 1. (a-c). Hybrid image composed of George Clooney and Brad Pitt’s faces. (a) A high pass filtered, thus sharpened image of George Clooney’s face is combined with (b) a low pass filtered, thus blurred image of Brad Pitt’s face to generate (c) a hybrid image of Sharp Clooney and blurred Pitt’s faces.} \]

One of the two images that form the final hybrid is created through a low-pass filter to remove the fine details while leaving the course structure of the image (thus making the image appear blurred to the observer), while the other image is produced
through a high-pass filter to keep and strengthen only its fine details. These two images (one created through a high pass filter and one created through a low pass filter) can be of anything but they must be different and easily superimposable in order to form one final cohesive image called the hybrid (an image that is formed from superimposing and combining two separate images).

The image (high pass or low pass) that is perceived is determined by the distance from the hybrid image itself. Fine details are visible when an observer is close in distance to the hybrid image while the blurred components of the second image can be seen from far away (Oliva et al, 2006, Oliva 2013). For example, in Figure 1a-c, the hybrid image is composed of two images; one of celebrity George Clooney’s face created through a high pass filter and the other of Brad Pitt’s face produced through a low pass filter. When the observer is very close to the hybrid image, he or she is more likely to see George Clooney’s face because the fine details are visible. However, at a further distance from the hybrid image, the observer is more likely to see Brad Pitt’s face because fine details cannot be perceived from further away (Oliva et al, 2006, Oliva 2013). In addition to distance, the image or component perceived from the hybrid image also depends on the relative contrast (or difference in brightness) of each image that composes the hybrid.

Hybrid images are useful tools of study with regards to adaptation as they can be used to simultaneously test the relative importance of two visual properties: the amplitude spectrum and the phase spectrum. Amplitude refers to the relative energy at each frequency (the amount of blur in the image), while phase refers to the positional information (the identity of the image). For example, in Figure 1, the phase spectra of the two images that form the hybrid image determines the identity of the faces (whether or
not the face is George Clooney or Brad Pitt’s face). The purpose of this study is to examine how the visibility of the images is affected by prior adaptation to the blurred or sharpened images. As noted above, many studies have examined adaptation to blur or faces, but none have examined how adaptation to one attribute transfers across or depends on the other. In this study, we used hybrid images composed of the faces of celebrities George Clooney and Brad Pitt, to cast the two important visual properties of blur and identity against each other by having the participant adapt to the original components or to images where the phase and amplitude are swapped. Thus, this study used hybrid images to test which aspect of the stimulus drives adaptation: the level of blur in the image or the identity of the image itself.

**Literature Review**

As stated, one hypothesis regarding the role of adaptation is that it functions to highlight new stimuli in the environment by desensitizing an individual to the stimuli already present in an observer’s environment (McDermott et al, 2010) The ability to distinguish novel stimuli from stimuli already present in the environment is essential for survival, especially when presented with a dangerous new stimulus (Raganath & Rainer, 2003). In the past, studies have been conducted to understand the impacts of adaptation with regards to many individual attributes of the world (Webster et al, 2002, Webster et al, 2004, Kaping et al, 2007, McDermott et al, 2010, Webster & MacLeod, 2011, King et al, 2015, Dong et al, 2016, Souto et al, 2016).

**Adaptation to Color and Objects**

In our day to day lives, we rely on the perception of simple stimuli such as objects and color, as reference points to categorize and describe our surroundings. For example,
recent study showed that adapting to larger objects before viewing a smaller object made the smaller object seem smaller than it was in actuality (Kingdom 2016). This result indicates that priming ourselves with or adapting to a particular stimulus prior to viewing a new stimulus in the environment, could greatly skew our perception of the world. Another example of adaption to simple stimuli is provided by McDermott and colleagues in 2010, who tested the effects of adaptation on the salience of color. When asked to find a color target in a dense color background, participants who were pre-exposed to the same color background as the one they subsequently had to search in were faster than participants who previously adapted to an orthogonal background different from the color background containing the target (McDermott et al, 2010). Findings such as these demonstrate that there is an adaptive effect with regards to color which can be beneficial in a variety of different fields, by making the novel colors in the scene more salient. For example, color may serve as a method to determine whether there are problems with an individual’s visual system and health. Many medical procedures that involve distinguishing benign tissues in the body from potentially cancerous tumors and tissues, rely on the medical personnel’s accurate perception of color through color coordinated medical displays (Mahn & Becht, 2016). Because priming the participants with the same color background as the one they had to subsequently search in resulted in a faster time for locating the target, it could be beneficial for medical personnel to adapt to the background color of the images generated by their machines prior to viewing the actual image in order to detect any potential health defects with greater accuracy and precision.
Adaptation to Faces

Along with simple stimuli, we are constantly faced with complex stimuli in the environment. One such stimulus is a face. Faces serve as a marker of identity and expression, two factors thought to be processed by levels of higher processing in the human brain (Leopold et al, 2005). Because humans are social creatures who rely on interaction, quick and reliable processing of facial features is essential. Thus factors that skew the judgement of faces are important to study. It has been shown that a particular face can be strongly skewed by the characteristics of faces seen prior (Webster & McLeod, 2011). For example, adapting to distorted faces prior to viewing a neutral undistorted face greatly biased the perception of the neutral face. If the distorted face to which a viewer adapted to was much thinner than a normally proportioned face, the normal undistorted face would then appear to be too large in its proportions (Webster & McLeod, 2011). Findings from experiments such as these establish that there is a strong adaptation effect for even for normal variations in faces, and suggest these adaptations are critical for calibrating accurate face recognition by allowing each individual to be judged by how they differ from the (adapted) prototype face.

Adaption to Blur

As established, blur is one of the most important stimuli for vision and a property that leads to strong adaptation. Whether or not an image is perceived as blurry to the observer depends on the balance of contrast (the variations in color or brightness) across the different spatial scales. For example, smoothing out the sharp edges of an image with a low spatial frequency filter can make an image appear blurred to the observer. Conversely, sharpening the edges of an image can make the image appear sharper than it
would be normally be perceived (Webster et al, 2002, King et al, 2015). This percepts are strongly biased by prior adaption to the blurred or sharp image. For example, adapting to a blurred image prior to viewing a normally in focus image makes the normal image appear too sharp (Webster et al, 2002).

**Adaptation in the Real World**

As discussed, various studies support the notion that adaptation may have an important role in sensitizing an individual to a new stimulus as opposed to one already present in the environment. The findings can potentially be used in a variety of different settings, particularly in clinical settings. For example, it has been shown that adapting to a x-ray image of a normal, healthy person makes it easier for abnormal masses to be detected when presented with a mammogram (Kompaniez-Dunigan et al, 2015).

Applying to the concept of adaptation to x-rays can then lead to a more accurate and efficient process of diagnosis for the patient. In addition, it has been demonstrated that visual and sensory adaptation is decreased in individuals with mental disorders like schizophrenia (Andrade et al, 2016). The results from this experiment may aid in trying to understand these deficiencies and improve them, thereby benefitting the lives of individuals who suffer from these types of disorders as well as their caretakers.

**Hybrid Images**

Hybrid images were created by Schyns and Oliva in 1999. Their study dealt with understanding whether categorization of an image was independent from the visual processing or perception of the image. The study used hybrid images composed of a man and woman’s face. Several categorization tasks were assigned to the participants such as
deciding whether the faces were male or female, whether the faces were expressive, or deciding which face had which expression. The results showed that the component perceived in the hybrid image (the high pass filtered image or the low pass filtered image) was heavily dependent on the categorization task given (Schyns & Oliva, 1999). This study was a gateway study for the use of hybrid images. However, there are not many studies utilizing hybrid images, particularly with regards to adaptation.

Because adaptation is so significant, it is very beneficial to continue to study how it guides our attention to novel stimuli. For this reason, and because the two visual properties of blur and identity can be tested simultaneously, we used hybrid images to test how adaptation alters the relative salience of features in an image, and how different features interact with regards to the adaptation.

**Methodology**

**Creation of Stimuli**

As adaptation is strong for faces (Webster et al, 2004, Leopold et al, 2005), we used two different faces to generate the hybrid images for this experiment. In particular, we generated hybrid images containing the faces of famous Hollywood actors, Brad Pitt and George Clooney. These actors’ faces were used for two reasons: their faces were very similar hence superimposable, and their faces were likely to be known to most members of the general public. We used a program in Visual Basic to code for and generate two arrays or sets of hybrids images with varying contrast. Each array contained 100 images.
Array A contained hybrid images composed of a low pass filtered (blurred) face of Brad Pitt and a high pass filtered (sharpened) face of George Clooney. The first image of Array A started with a completely blurred image of Brad Pitt’s face and shifted towards a completely sharpened image of George Clooney’s face. The pictures in between the first and 100th image in the array were hybrid images created with varying contrasts of the blurry version of Brad Pitt’s face and the sharpened version of George Clooney’s face. Essentially, varying percentages of the blurred image of Brad Pitt and sharpened image of George Clooney were used to generate each hybrid image in the array. An illustration of the first array can be seen in Figure 2.

![Array A: Blurred Pitt to Sharp Clooney](image)

*Figure 2. Array A. Going from blurred image of Brad Pitt’s face to a sharpened image of George Clooney’s face*

Array B was generated in a similar fashion. However, Array B consisted of hybrid images composed of a high pass filtered (sharpened) image of Brad Pitt and a low pass
filtered (blurred) image of George Clooney. The array started with a completely sharpened image of Brad Pitt’s face and shifted towards a blurred image of George Clooney’s face. The hybrid images in this array were generated by varying the contrasts of the sharpened image of Brad Pitt and the blurry image of George Clooney. An illustration of Array B can be seen in Figure 3.

*Figure 3.* Array B. Going from sharpened image of Pitt’s face to blurred image of Clooney’s face.
Participant Recruitment

Prior to recruiting participants, my co-experimenter and I conducted pilot runs on ourselves to ensure that the whole experimental procedure ran smoothly, and to verify that the stimuli supported adaptation effects.

This study involved five participants composed of both undergraduate and graduate students from the University of Nevada, Reno. As per IRB, our participants were required to be students from the university. Because this study was a visual study, participants were also required to have normal or corrected vision to take part in the experiment. All participation was with informed consent and followed the protocols approved by UNR’s IRB.

The experiment required participants to come back four separate times for four different sessions. Participants received ten dollars per hour of their time. In addition, prior to the start of the actual experiment, each potential participant was asked to attend a training session of 30 minutes to determine their availability and fitness for the task. The 30 minute training session first involved a complete explanation of the consent form and the general expectations we had from each participant. Following the explanation and signing of the consent form, a slideshow containing the faces of Brad Pitt and George Clooney were shown to each participant in case they were unfamiliar with the celebrities’ faces. The slideshow also contained sharpened and blurred images of each of the celebrities’ faces as well as hybrid images of their two faces combined so that the participants had an idea of what to expect from the study.
Lastly, the potential participants were asked to take part in a few short baseline runs: two short runs containing images from Array A and two short runs containing images from Array B. In these practice runs, a hybrid image from any point of either array, was displayed on the screen and the participant was asked to signal by pressing buttons whether the image appeared more like George Clooney or Brad Pitt. The contrast of the hybrid image displayed was varied in a staircase method based on the participants’ responses. For example, if the participant indicated that he or she found Clooney’s face to be more visible, the program adjusted the relative contrasts of the two images in the hybrid by increasing the Pitt contrast and decreasing the Clooney contrast. This was repeated until the participant responded that Pitt was more visible. The hybrid images moved up or down through the array in order to estimate the contrast (or point in the array) at which both faces were equally visible. These small practice runs were used to analyze the contrast balance of the images for each participant prior to the adaption stage. These practice runs were also a method of making sure that the participants were aware of how to navigate through the experiment. At the end of the 30-minute training session containing the slideshow and the small practice runs, the participants had the opportunity to leave or stay in the experiment.

Each of the participants who stayed, took part in all stages of the experiment for a total of five to seven hours depending on the participant and his or her responses. The small sample size of the study allowed for each participant to partake in each procedure of the experiment. Thus, the experiment followed a within-subject rather than a between-subject design, a common procedure in perception research which helps reduce the variability or noise between conditions.
**Experimental Design**

Each participant took part in four separate sessions after the 30-minute training session. The program used for each part of the experiment was coded in MATLAB. Each session varied from one hour to two hours in length, depending on the participant and his or her responses. Since the way a hybrid image is perceived also depends on the distance from the image, the distance was kept constant at one meter from the participant’s eye to the computer screen. Thus, perception was manipulated by the varying contrasts of the two images that composed the hybrid image.

Each of the four sessions consisted of a preadaptation phase and an adaptation phase. The preadaptation phase was composed of two baseline runs that mimicked the practice runs given to the participants in their 30 minute training sessions. (one run with images from Array A and one run with images from Array B). Like in the training session, these baseline runs were used to analyze the contrast balance for the images for each participant prior to the adaptation stage.

After the preadaptation stage, the adaptation stage began. Participants were asked to view one of the four images from extremes of each array. In other words, the participants were asked to view either the completely blurred image of Pitt that started array A, the sharpened image of Clooney that ended array A, the sharpened image of Pitt that started array B, or the blurred image of Clooney that ended array B. The participants viewed one of these four images on the computer screen for a period of 180 seconds in order to adapt to or become desensitized to the image before viewing images at random from one of the two arrays.
During the 180 seconds of adaption, nine identical images were shown in a 3 by 3 matrix, with the position of the matrix randomly jittering on the screen. This procedure was used to prevent simple light adaptation aftereffects at each point in the image. After the adaptation process, each run displayed images at random from either Array A or Array B. The participants were asked in the similar fashion as the baseline conditions, to indicate whether they found George Clooney or Brad Pitt’s face to be more visible. Between each response, the participants were briefly flashed with the adapt image again for five seconds before being displayed with another test image. These adaptation “top-ups” were included to maintain the adaptation effect throughout the test sequences. Once again, the program ran until the participants responded to seeing both Brad Pitt and George Clooney with equal frequency. A demonstration of the stimulus display and experimental set-up is shown in Figure 4.

Figure 4. Summary of Experimental Set up
Because there were four adapt images, there were four runs with Array A and four runs with Array B, leading to a total of eight adapt conditions. A summary of the eight adapt conditions is illustrated in Figure 5.

Figure 5. Summary of 8 Adapt Conditions. The adapt conditions did not follow the same order across sessions in order to prevent biasness from being accustomed to the order

The eight adapt conditions were tested in random order across sessions. There were a total of 10 conditions tested at each of the four sessions: two baseline conditions and eight adapt conditions. The responses generated from the adapt conditions were analyzed to determine the shift from the baseline condition responses.
Follow-Up Experiment: The Effect of Task

Because the factor that drives the adaptation aftereffect could be task dependent, a follow-up experiment was run with the same stimuli used in the first experiment. However, in this experiment, participants were asked to indicate whether the test image was too blurry or sharp instead of whose face was more visible. This part of the study is ongoing with participants having completed between 2-4 runs.

Control Experimental Design

In order to interpret the results obtained from the main experiment, we tested two of the participants in two control experiments to confirm that faces and blur can create adaptation aftereffects on their own. These controlled experiments were similar in setup to the main experiment. However, instead of testing two types of visual stimuli simultaneously, only one type of stimulus was tested per control experiment. The stimuli were created with the same program that generated the stimuli for the main experiment.

The blur control experiment involved two arrays of 100 images each. One array contained only Brad Pitt’s face while the other array contained only George Clooney’s face. The blur was varied in each of the array. The array containing Brad Pitt’s face started with a completely blurred image of his face and moved towards a completely sharpened image of his face. The array containing George Clooney’s face was similar as it started with a blurred image of his face and moved towards a sharpened image of his face. The illustration of this design can be seen in Figure 6.
This follow up experiment sought to establish that blur adaptation occurs regardless of the face or identity of the image. Thus, for the George Clooney array, the participant viewed either the completely blurred image of George Clooney at the beginning of the array or the sharpened image of George Clooney for a period of 180 seconds, similar to the main experiment. After this adaptation period, any image from only the George Clooney array was displayed in a similar fashion to how the images were displayed in the main experiment. However, this time the participant answered whether they believed that the image was too sharp or too blurry compared to what he or she thought a normal focused image would look like. The same procedure took place for the Brad Pitt array. A summary of the adapt levels can be seen in Figure 7.
Figure 7. Blur adapt control conditions

The face control experiment was also designed in a similar fashion with two arrays of 100 images each. However, this time only the face varied and not the level of blur. One array was blurred completely and that level of blur was maintained, while the other array contained only completely sharpened images. Both arrays started with Brad Pitt’s face and eventually merged into George Clooney’s face. Percentages from each face were used to generate the mixture of the faces in each array. An illustration of the two arrays and the direction they flow in can be seen in Figure 8.
Figure 8. Face control experiment arrays

The experimental design followed a similar set up to the blur control where the participant viewed and adapted to the opposite extremes of each array for 180 seconds (ie. the Brad Pitt end or the George Clooney end of the blurred array, or the Brad Pitt or George Clooney end of the sharp array) before viewing images from that particular array, similar to the experimental set up from before. The task was to determine whether the image was visibly more Clooney or more Pitt without the effect of blur. A summary of the adapt conditions is displayed in Figure 9.
The results of the first experiment suggest that face or identity of the image drives adaptation when the task was to report the perceived identity of the faces. Figure 10 shows the average shifts from the baseline (scaled so the baseline is at 0) with regards to face effects across both arrays.
Figure 10. Graphical representation of average shifts from baseline. There are significant shifts with regards to face effects only (error bars= ± 1SEM)

Shifts are significant with regards to face differences but not blur level (error bars= ± 1 SEM). For example in Figure 10, it can be seen as an overall general trend that when adapted to Brad Pitt’s face, the responses shift much more towards Brad Pitt’s face regardless of the level of blur. Also, when adapting to George Clooney’s face, the responses shift more towards Clooney’s face regardless of the level of blur. This indicates the participant had strongly adapted to or become desensitized to the face so a higher concentration of that particular face was needed in order to visualize it.
On the other hand, there was not much of an adaptation to the level of blur.

Figure 11 depicts adaptation effects specific to adaptation level and array across both arrays.

![Figure 11](image)

*Figure 11. Adaptation effects specific to adaptation level. Shifts are significant based on adapt level conditions: shifts are significant with regards to face but not blur*

The findings indicate that even across specific adaptation levels, there are only significant shifts with regards to face effects.

A statistical program called SPSS was used to analyze the significance of the data. First a 2 by 2 ANOVA was generated to simultaneously test the effects of blur and face across both arrays. Table 1 shows that the effects of face is most significant in adaptation (p<0.05) while the effects of blur level is not significant (p=.805).
There is also no significant interaction between the two stimuli, meaning that they do not work together to drive adaptation (p=.120).

Table 1. Simultaneous effects of blur and face over both arrays. Face or identity is greatly significant in driving the adaptation.

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a. R Squared = .638 (Adjusted R Squared = .607)

A 2 by 4 ANOVA was also generated using SPSS to see the individual interactions between each individual adapt level and to determine whether the array itself made a difference on adaptation. Table 2 shows the results of this ANOVA and it can be seen that the array itself had little effect on adaptation (p=.498). Conversely, the adapt level or condition is significant in determining the shifts from the baseline (p<0.05). There is no significant interaction between the variables of array type and adaptation level (p=.445).
Table 2. Adaptation effects specific to adaptation level and array. Shifts from baselines are significant depending on the adaptation level and not significant based on the array.

![Table](attachment:image.png)

**Effect of Task**

Conversely, when asked to determine whether the test image was too blurry or sharp when presented with the same stimuli as above, the results indicate a significant shift from the baselines with regards to blur level instead of facial differences. Figure 12 shows the significance between adapt levels for both arrays. A 2 by 4 ANOVA was again generated via SPSS to see the individual effects across specific adapt conditions. Results indicate that there is significant shifts between blur level adapt conditions but not between the different faces.
Figure 12. Adaptation effects specific to adapt levels. There are significant shifts from the baseline with regards to differences in blur level but not face (NS denotes not significant and error bars= ± 1SEM.

Figure 13 is a graphical representation of a 2 by 2 ANOVA comparing blur and face adaptation aftereffects over both arrays. The results indicate that there are significant shifts from the baseline with regards to blur level but not with regards to face differences.
A representation of the 2 by 2 ANOVA generated by SPSS, comparing the simultaneous effects of face and blur levels can be seen in Table 3. Results show that there is a significant effect of blur level on adaptation (p < .05) while there is no significant adaptation effect with regards to faces (p = .239). There is not significant interaction between the two attributes to drive adaptation (p = .437).

Figure 13. Comparison of blur and face adaptation aftereffects over both arrays. There are significant shifts from the baseline with regards to blur level effect (left) and no significant shifts with regards to face differences (right)
Table 3. Simultaneous effects of face and blur over both arrays. Blur level is significant in driving the adaptation aftereffect. There is no significant effect of face or any significant interaction between the two attributes.

Table 4 is a representation of a 2 by 4 ANOVA which compared individual interactions between the different adapt conditions, testing to see whether the array itself made a difference in the adaptation effect obtained. Results indicate that there the adapt condition itself was significant (p < .05) while the array itself did not have any significant effect on the shifts from the baselines (p = .168). There was no significant interaction between adapt condition and the array type (p = .523).
Table 4. Adaptation effects specific to adaptation level and array when asked to determine blur level. Shifts from baselines are significant depending on the adaptation level and not significant based on the array. Blur level is significant.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>8982.974^a</td>
<td>7</td>
<td>1283.282</td>
<td>10.791</td>
<td>.000</td>
</tr>
<tr>
<td>Intercept</td>
<td>12.358</td>
<td>1</td>
<td>12.358</td>
<td>.104</td>
<td>.750</td>
</tr>
<tr>
<td>Adapt_Condition</td>
<td>8468.316</td>
<td>3</td>
<td>2822.772</td>
<td>23.736</td>
<td>.000</td>
</tr>
<tr>
<td>Array</td>
<td>240.485</td>
<td>1</td>
<td>240.485</td>
<td>2.022</td>
<td>.168</td>
</tr>
<tr>
<td>Adapt_Condition * Array</td>
<td>274.173</td>
<td>3</td>
<td>91.391</td>
<td>.768</td>
<td>.523</td>
</tr>
<tr>
<td>Error</td>
<td>2854.141</td>
<td>24</td>
<td>118.923</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11849.473</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>11837.115</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A complete follow up control experiment could not be completed in the time we had, however the results that we were able to obtain from the controlled blur and face adaptation experiments support previous data and suggest that blur level and faces both generated adaptation aftereffects on their own (Figures 14 and 15 respectively). For instance, in Figure 14a-b, when adapting to a blurred version of a face, the trends show that a greater concentration of the blurred face is need in order to perceive the blur in both arrays. In Figure 15a-b, when adapting to one of the faces, the participant is more likely to the other face and therefore needs a greater concentration of the face he or she adapted to in order to perceive it.
**Figure 14.** Blur Control Results. (a-b) Results suggest that blur level itself can create an adaptation aftereffect.

**Figure 15.** Face Adapt Control Results. (a-b) Results suggest that faces can create an adaptation aftereffect on their own.
**Discussion of Results and Conclusion**

The results of this study indicate that adapting to one component of the hybrid image makes the other component of the hybrid more salient, supporting the existing hypothesis that adaptation functions to highlight the visibility of novel stimuli by becoming desensitized to stimuli already present in the observer’s surroundings. Furthermore, the results of the study suggest that the component that drives adaptation is largely task dependent. When observers were asked to judge the identity of the faces, the differences in the faces completely drove the adaptation aftereffect. Conversely, when the participants were asked to judge the level of blur, the differences in blur level completely drove the adaptation aftereffect. Thus, these results suggest that the visual system can act independently on both the phase (face) and amplitude (blur) spectra of the images, depending on what is in focus.

However, will these obtained results hold true for all types of images or are they unique to faces since faces are structurally similar? In the future it would be interesting to see whether combining two very dissimilar images would lead to the same results. For example, Figure 16 shows a potential study direction where a high pass filtered image of ocean waves are combined with a low pass filtered image of dunes to generate a hybrid. Because the spectra of these images such as these are so different, it would be eventually be difficult to determine the identities of the images. Thus, it would be interesting to see whether blur levels drive the adaptation in this case.
Overall, results of this study could be prove to be significant in a multitude of different fields, such as in healthcare. For example many medical personnel are required to quickly identify foreign substances in medical reports. Knowing that adaptation is task dependent could result in better and faster training in locating potentially harmful threats, if one knows what aspect to focus on. Moreover, the results obtained from this study can help to further understand how the visual system adjusts to our surroundings and the potential purpose of these

Figure 16. Hybrid image created from images of waves and dunes
References


Appendix: Consent Form

University of Nevada, Reno
Institutional Review Board

Approved on: January 13, 2017

UNIVERSITY OF NEVADA, RENO SOCIAL BEHAVIORAL INSTITUTIONAL REVIEW BOARD

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Title of Study: Contrast Adaptation and the Statistics of Natural Images Principal Investigator: Michael Webster, Ph.D 775-682-8691
Co-Investigators: Katie Mussell, Siddhart Srivatsav, Kara Emery, Talia Retter, O. Scott Gwinn, Tiziana Vercillo, Ivana Ilic, Noirita Saha
Protocol Number: SB93/94-23

Sponsor: NIH NEI

Purpose. You are being asked to participate in a research study. The purpose of this study is to learn about the ways in which people perceive the color or the shapes of objects, and how their perception changes depending on the colors or objects that they are currently viewing. We will do this by having subjects view patterns presented on a television screen, and then asking subjects to report the perceived color or shape of a set of patterns. In this way we hope to learn about the properties of adaptation in the normal visual system and how it influences our perception of color and form.

Subjects. You have been asked to participate in this research because you have normal color vision and normal or corrected visual acuity. To participate as a subject you must be 18 years of age or older and a UNR student.

Procedures. If you choose to participate, you will be asked to attend a one-hour session in which you will participate in experiments. The experiments will be carried out in the UNR Psychology Department and will involve viewing and responding to stimuli presented on a color television. The stimuli will typically be a colored square presented on the screen whose color and brightness change over time, a random looking texture, or a distorted image of a human face. After viewing these “adapting” stimuli for a few minutes, you will be presented with a test stimulus. The purpose of the experiments is to measure how the appearance of the test stimulus is affected by prior viewing of the adapting stimulus. You will be asked to judge the appearance of the test by using a set of buttons to adjust the test stimulus or a nearby “matching” stimulus. For example, you might adjust the appearance of a face until it appears to have a neutral gender (so that it appears neither male nor female) or a neutral age (so that it does not appear young or old). For a subset of experiments, eye position will be recorded while viewing the stimuli, in which case you will be asked to view the display while resting your head on a chin rest so that a camera can track your eye position.

Risks. The visual experiments require only that you attend to and make simple judgments about patterns displayed on a standard video screen. The procedures and equipment we will use are in widespread use in research on visual perception and have no known risks associated with them.

Benefits. The study is designed to further our knowledge of the human visual system and may not directly benefit you as an individual. However, your participation will provide you with first-hand experience in research studies of the visual system. At the end of your participation you will be fully informed about the results of your observations and their implications for the theoretical aims of the study.
University of Nevada, Reno
Institutional Review Board

Approved on: January 13, 2017

Title of Study: Contrast Adaptation and the Statistics of Natural Images
Investigator: Michael A. Webster, Ph.D. 775-682-8691

Co-Investigators: Katie Mussell, Siddhart Srivatsav, Kara Emery, Talia Retter, O. Scott Gwinn, Tiziana Vercillo, Ivana Ilic, Noirita Saha

Protocol Number SB93/94-23
Sponsor: NIH NEI

Confidentiality. Your identity will be protected to the extent allowed by law. You will not be personally identified in any reports or publications that may result from this study, and all data will be collected with only participant numbers as identification. The measurements are being collected for research purposes only. Records of your observations will be stored in the office or laboratory of the Principal Investigator and will be made available only to researchers directly involved in the study or authorized University officials (including the University of Nevada, Reno Social Behavioral Institutional Review Board).

Costs/Compensation. There will be no cost to you for participating in this study. Student participants will receive extra credit for participating in this study.

Right to Refuse or Withdraw. You may refuse to participate or withdraw from the study at any time without penalty. If you choose to withdraw from the study, if you are a student you will still receive extra credit. If the study design or use of the data is to be changed, you will be so informed and your consent re-obtained. You will be told of any significant new findings developed during the course of this study which may relate to your willingness to continue participation.

Questions. If you have any questions, please ask us. If you have additional questions later, contact Michael Webster, Ph.D. at the Department of Psychology, 775-682-8691; or Katie Mussell, Siddhart Srivatsav, Kara Emery, Talia Retter, O. Scott Gwinn, Tiziana Vercillo, Ivana Ilic, Noirita Saha at the Department of Psychology, 775-682-8669.

You may report (anonymously, if you so choose) any comments or complaints regarding the manner in which this study is being conducted to the University of Nevada, Reno Institutional Review Board (775-327-2368). Letters may be addressed to:

Chair of the University of Nevada, Reno
Institutional Review Board
C/O UNR Office of Human Research Protection
218 Ross Hall, Mail Stop 331
Reno, NV  89557

Closing Statement
(12/12/14 rev.)  Page 2 of 3
Title of Study: Contrast Adaptation and the Statistics of Natural Images

Investigator: Michael A. Webster, Ph.D. 775-682-8691

Co-Investigators: Katie Mussell, Siddhart Srivatsav, Kara Emery, Talia Retter, O. Scott Gwinn, Tiziana Vercillo, Ivana Ilic, Noirita Saha

Protocol Number SB93/94-23
Sponsor: NIH NEI

I have read ( ) this consent form or have had it read to me ( ). [Check one.]

________ has explained the study to me and all of my questions have been answered. I have been told of the risks or discomforts and possible benefits of the study. I have been told of other choices of treatment available to me.

If I do not take part in this study, my refusal to participate will involve no penalty or loss of rights to which I am entitled. I may withdraw from this study at any time without penalty [or lose other benefits to which I am entitled].

I have been told my rights as a research subject, and I voluntarily consent to participate in this study. I have been told what the study is about and how and why it is being done. All my questions have been answered.

I will receive a signed and dated copy of this consent form.

Signature of Participant Date

Signature of Person Obtaining Consent Date