# Feature repetition effects on object familiarity: Evidence from an old/new recognition task

**Selda Eren (e115275@metu.edu.tr)**
Department of Cognitive Science, Middle East Technical University
Ankara, 06531 Turkey

**Annette Hohenberger (hohenberger@ii.metu.edu.tr)**
Department of Cognitive Science, Middle East Technical University
Ankara, 06531 Turkey

## Abstract

We performed an old/new study/test recognition task to investigate feature repetition effects on object familiarity. The results showed that repeated features increased "old" responses during the test phase for new objects. This increase was linear with the number of repeated features on the object. Old objects, which had been among the study phase stimuli, were not affected by the number of repeated features on the object. We also analyzed the effect of feature type (colour, shape, border and pattern) on familiarity responses. We found an effect of feature type only for the old objects. Saliency of the features also affected familiarity: the more salient the repeated feature was, the more familiar the object was found. We propose that the feature repetition effect for the new objects might be due to (1) activation of more than one representation constructed during the study phase (2) a separate representation for the repeated features, which has the potential to interfere with several perceptual processes.

**Keywords:** feature repetition effect; object recognition

## Introduction

Formation and activation of perceptual representations has been the subject of various disciplines including, but not limited to, philosophy, psychology, psychophysics, neuroscience, and computer science. In philosophy, the existence of "mental representations" is a fundamental debate in the philosophy of mind. In psychology, the studies of categorization and memory directly relate to this problem. Artificial intelligence and robotics research concentrate on implementing visual systems that construct a representation of their virtual or real environments. With the emergence of cognitive science, the bodies of knowledge that developed in these separate fields are coming together, for a better understanding of how perceptual representations are constructed and accessed. This study aims to contribute to the research on the formation and activation of visual object representations by revealing some important factors involved in memory processes. Our approach takes its roots from findings in perception and memory literature and computational approaches in artificial intelligence.

From a computational perspective, it is possible to represent everything in the environment as a combination of some features, like color, shape, pattern, etc. We know that the human brain has specialized areas for each of these feature domains (Hanna & Remington, 1996). Whenever a visual scene is encountered, activation is observed in these areas. Is this a mere bottom-up activation, or does the perceptual system attend to specific areas in the scene? We know that the visual system is not a passive receiver of visual data, but it actively obtains information from the visual flux (Jingling & Yeh, 2007). Attention makes a difference but we do not know whether the representation is stronger or the conscious access is easier in this case.

Whether the features in the scene are selected or all stored, it is clear that a combination of these features constitutes visual representations (Slotnick, 2004). Also audial and tactile features can be integrated with visual features, in which case the resulting representation can be called an "event file" (Hommel, 1998). Hommel states that all the features perceived in the same temporal window are automatically stored in these event files. These files can include features of every type, blurring the distinction between different domains of features, including visual and spatial pathways, which are assumed to exist separately in the brain. He points to the importance of building arbitrary connections between the features from different domains for learning.

In this study we investigated feature repetition effects on object familiarity. Hommel and Colzato (2009) report a decrease in performance in a stimulus-response task when one object feature is repeated while other features varied, as compared to complete repetitions and alterations. We predicted that repetition of particular features while other features vary would also affect familiarity of objects. We aimed to test this prediction with a continuous old/new study/test recognition design. In the study phase, participants saw a series of items one by one. In the test phase, they evaluated familiarity of the test items. To create the feature repetition effect, particular features were displayed more frequently than the other features in the study phase. We will call these features "frequently repeated features" (FRFs). In the test phase, items either had none, one, or two of the FRFs. We expected that the more FRFs the item had, the more participants would classify the item as familiar. We obtained scores for hits, misses, correct rejections and false alarms. False alarm scores are especially important for our purposes. If items that were not displayed in the study phase are yet found familiar when they have FRFs, this would mean that (1) activation of previous bindings do not require an exact match with the given stimulus, or (2) there are other factors than binding of features that influence a familiarity judgement. If false alarms increase linearly with the # of FRFs, this might indicate an accumulated effect of repetition frequency on this judgement.

The design of the experiment is similar to the experiments in the categorization literature. In these experiments, a set of training objects are presented to the participants. In the test phase, they are expected to identify which category each test object belongs to. The features of the training objects are manipulated so that the effects of various variables such as similarity can be analyzed. However, our experiment significantly differs in the following terms: We do not assume a categorization process. Participants do not necessarily construct a categorical representation of the training stimuli and making familiarity judgements do not necessarily require accessing categorical representations.

The task in our experiment differs from the classical old/new recognition tasks, too. The usual old/new recognition task aims investigating the memory performance with respect to the dynamics of serial presentation of the stimuli. In our experiment, we systematically controlled the statistical properties of the object features and tested the effect of individual and combined feature repetitions instead of whole objects. In short, it can be said that our experiment integrates elaborate manipulations of object features as in categorization studies and experimental structure of an old/new recognition task. This provides a way of investigating the mechanisms of formation of perceptual representations through an analysis of the relationship between the statistical properties of the perceived stimulus and familiarity responses.

Another issue is feature intensity. Object representations in visual LTM have different intensities. The graded nature of these intensities shows its dominance in object recognition tasks, where object-based effects are tested (Ariga, Yokosawa, & Ogawa, 2007). In one task, participants were asked to recognize a target object in different conditions. In the first condition, the object was presented with a cue and in the second condition with no cue. Participants were faster at responding to objects presented with a cue only when the displayed object has a LTM representation of high intensity.

Finally, we investigated whether the type of feature is important for the feature repetition effect. Table 1 shows the feature types and values that appear in the stimuli set. By repeating different pairs of features, we analyzed familiarity responses for colour/border and shape/pattern pairs. In the next section the details of our design will be explained.

## Method

### Stimuli

**Features** There were four types of features: colour, shape, border and pattern. Each type had three values, as shown in Table 1. It was possible to create 81 objects using 4 features with 3 different values ($3^4$).

Table 1: Feature types and values used in the experiment

| | | | |
|---|---|---|---|
| **Colour** | Red | Green | Blue |
| **Shape** | Square | Triangle | Circle |
| **Border** | Solid black | Dashed black | Coloured |
| **Pattern** | Dots | Diagonal lines | Shingle |

**Objects** There were 15 objects. Objects were chosen among the pool of 81 possible objects, according to the following criteria: Solid black border and green color (pair 1) repeated together on 5 objects (see Figure 1a for an example of such object). Diagonal line pattern and square shape (pair 2) repeated together on 5 objects (see Figure 1b). Other feature pairs existed on 2 objects at most. FRFs were solid black border, green color, diagonal line pattern, and square shape, each repeating 7 times. Other features repeated only 4 times, e.g. 4 objects had blue color. Objects were created using the AutoShape tool of Microsoft Power Point. Objects had the same height (5 cm) and width (5 cm).

**Slides** One object was displayed on each slide. The center of gravity of the object was aligned to the center of the slide.

**Training and test files** There were 15 slides in the training file. Each slide was displayed for 2 seconds. Slide transitions were automatic. In the test file, there were 18 slides. The order of the slides was reversed in half of the participants. 8 slides were copied from the training file. The objects on these slides were the actual "old" objects. Remaining slides contained new objects. Each slide was displayed for 3 seconds.

Table 2: Number of objects of each category in the test phase.

| | Old | New |
|---|---|---|
| Objects with two FRFs – pair 1 | 2 | 2 |
| Objects with one FRF – pair 1 | 1 | 2 |
| Objects with two FRFs – pair 2 | 2 | 2 |
| Objects with one FRF – pair 2 | 1 | 2 |
| Objects without any FRFs | 2 | 2 |
| Total | 8 | 10 |

## Participants

20 participants participated in the experiment. The age of the participants ranged between 22 and 35 years. All participants were university graduates. Participants had normal or corrected-to-normal vision. People who reported to be colorblind were not accepted to the experiment.

## Experimental Design

There were two independent variables: familiarity and number of FRFs. Familiarity had two values: old or new. Number of FRFs had three values: 0, 1 and 2. The dependent variable was the familiarity score. It is the average of familiarity responses given to the objects in a category. Categories are displayed in Table 2. This was a 2x3 repeated measures design.

## Setting

Computers in the Informatics Institute Computer Lab were used for the experiments. Stimuli were presented on a 19" widescreen LCD monitor by Microsoft Power Point software.

(a)

(b)

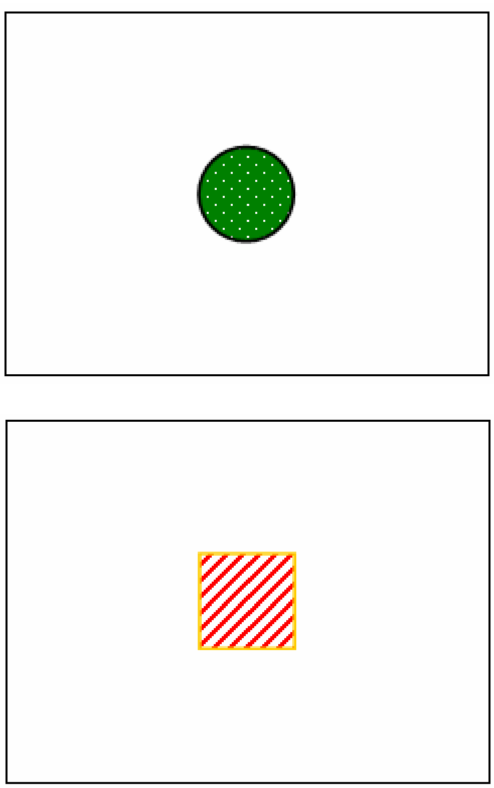


Figure 1 : Example stimuli from the study phase of the first experiment. These objects include features that have high repetition frequency (a) Green color and solid black border (b) Oblique pattern and square shape

## Procedure

Before the experiment, participants signed an informed consent form. The instructions were as follows:

"The experiment consists of two parts. In the first part, you will see a series of slides. There will be objects on these slides. In the second part, I will show you another series of slides and ask you whether the object is familiar from the previous part."

The experimenter opened the Power Point file. "Press spacebar to continue" displayed on black background.

"You will press the spacebar when you are ready to start the first part. You will just watch the slides."

After all 15 slides were displayed, the Power Point turned back to the design view. At that point, the experimenter started the training slides from the beginning and instructed the participants as follows:

"Now I will repeat the same slides for better recall."

After the second round, the experimenter opened the test file, and gave the following instructions:

"I will show you a series of slides and ask if the object is familiar from the first part. Reply with Yes or No. Since there is a time limit, try to be as quick as possible." As the subject responded to each slide, the experimenter noted +/- marks on a response sheet.

## Results

First, the familiarity scores for each category were calculated. The familiarity score is the average of the familiarity responses given by the participants to the test objects in a category. For example, if the participant responded with "familiar" to both objects the familiarity score was 1 ($response_1$= 1, $response_2$= 1, average($response_1$, $response_2$)= 1). If one of them was familiar, and the other one was unfamiliar, the familiarity score was 0.5 ($response_1$= 1, $response_2$= 0, average($response_1$, $response_2$)= 0.5). If both objects were unfamiliar the familiarity score was 0 ($response_1$= 0, $response_2$= 0, average($response_1$, $response_2$)= 0 ). Counts of familiarity responses are displayed in Table 3.

**Color and border** We analyzed the effect of repeating the features green color and solid black border on familiarity responses. The effects of the two independent variables, familiarity (old, new) and the number of FRFs (0, 1, or 2), were analyzed in a two-way repeated measures ANOVA. There was a main effect of familiarity ($F(1,19)=46.77$, $p<0.001$, e=0.7[1]), a main effect of number of FRF ($F(2,38)=13.57$, $p<0.001$, e=0.4) and an interaction between familiarity * number of FRFs ($F(2,38)=3.57$, $p<0.05$, e=0.2). The mean familiarity score was higher for the old objects, objects which actually existed in the set of the stimuli of the study phase, and the main effect of familiarity implies that this was significant. In other words, participants could successfully remember the

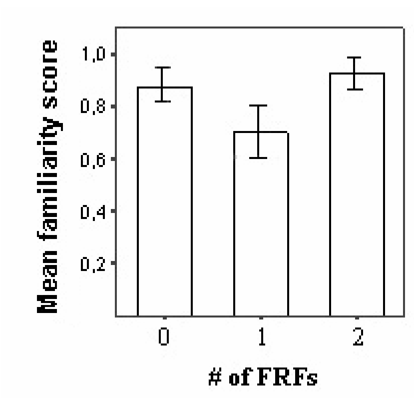
[1]"e" denotes "partial eta square".

Table 3 : Responses for the old/new recognition task. The numbers '0', '1' and '2' at the top of each column correspond to the number of FRFs on the object.

| Response | Stimulus | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Color and border repeated | | | | | | Shape and pattern repeated | | | | | |
| | Old | | | New | | | Old | | | New | | |
| | 0 | 1 | 2 | 0 | 1 | 2 | 0 | 1 | 2 | 0 | 1 | 2 |
| "Old" | 35 | 28 | 37 | 9 | 16 | 27 | 35 | 36 | 32 | 9 | 17 | 28 |
| "New" | 5 | 12 | 3 | 31 | 24 | 13 | 5 | 4 | 8 | 31 | 23 | 12 |

objects that had been presented to them before. The main effect of number of FRFs shows that the familiarity response of the participants was affected by the number of FRFs on the object. As the number of FRFs increased, the mean familiarity score increased. The third significant effect is the interaction effect. In Figure 2, the different patterns of responses for familiar and unfamiliar objects can be seen. The number of FRFs did not affect mean familiarity scores for the familiar objects. However, for the unfamiliar objects, we see a totally different picture. If the object had no FRFs, then most of the participants reported that they had not seen the object before. If the object shared only one of the FRFs, the mean familiarity score doubled. Finally, if the object shared both of the FRFs, most of the participants reported that they had seen the object, although they had not.

(a)




(b)

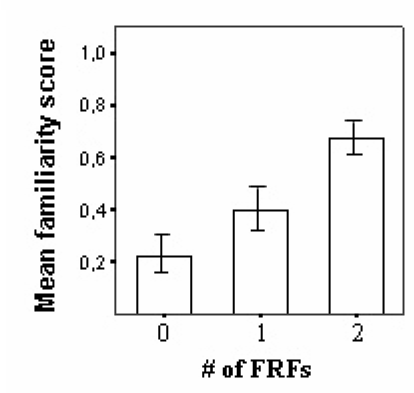



Figure 2: Mean familiarity scores for the objects with zero, one or both of the features color green and solid black border. Error bars represent standard error
(a) Old objects (b) New objects

**Shape and pattern** Likewise, for the second pair, the square shape and the diagonal lines pattern, the effects of familiarity (old, new) and the number of FRFs (0, 1, 2) were analyzed with a two-way repeated measures ANOVA. There was a main effect of familiarity ($F(1,19)=28.89$, $p< .001$, e=0.6), a main effect of number of FRFs ($F(2,38)=5.67$, $p< .01$, e=0.2) and an interaction between familiarity * number of FRFs ($F(2,38)=10.89$, $p< .001$, e=0.4). The mean familiarity score was higher for the old objects, objects which existed in the set of stimuli and the main effect of familiarity implies that this was significant. The main effect of number of FRFs shows that the familiarity response of the participants was affected by the number of FRFs on the object. As the number of features increased, the mean familiarity score also increased. The third significant effect is the interaction effect. In Figure 3, the different patterns of responses for familiar and unfamiliar objects can be seen. The number of FRFs did not affect mean familiarity scores for the old objects. For the new objects, however, we see an effect of FRFs. If the object had no FRFs, then most of the participants reported that they had not seen the object before. If the object had only one of the FRFs, the average familiarity score doubled. Finally, if the object had both of the relevant features, most of the participants reported that they had seen the object.

**Effect of feature types on familiarity responses** The aim of this analysis is to test whether there was a difference between effects of repeating the color/border pair and repeating the shape/pattern pair on the familiarity judgment of objects. Mean familiarity scores for each pair are depicted in Figure 4. p1 represents the feature pair green color/black border and p2 represents the feature pair square shape and diagonal lines pattern. For hits, we see a slightly different pattern for p1 and p2. For false alarms, familiarity responses for p1 and p2 are almost identical. In this analysis we want to check whether the difference between p1 and p2 for the hits is significant. Two 2 (# of FRFs: 1, 2) x 2 (feature pair: 1, 2) repeated-measures ANOVA were

(a)

(b)

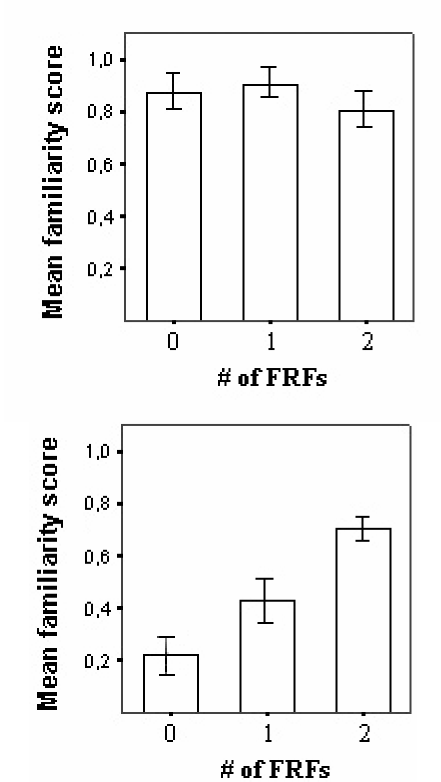



Figure 3: Average familiarity scores for the objects with zero, one or both of the features square shape and diagonal lines pattern. Error bars represent standard error (a) Old objects. (b) New objects.

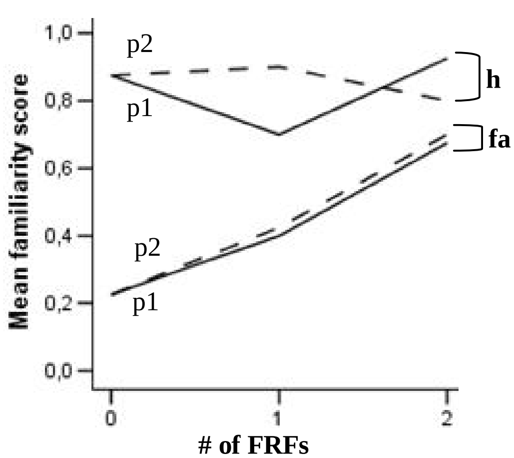



Figure 4: Familiarity scores for hits and false alarms for two different feature pairs. h denotes hits and fa denotes false alarms. p1 represents the feature pair green color/black border and p2 represents the feature pair square shape and diagonal lines pattern.

performed separately for hits and false alarms. For false alarms, there was no significant difference. For hits, there was an interaction effect between feature pair and # of FRFs, $F(1,19)=4.65$, $p< .05$, $e=0.26$). The interaction effect showed that as the “old” responses increased with the # of FRFs for the objects with green color and solid black border, a decrease was observed for the objects with square shape and diagonal lines pattern.

## Discussion

We obtained three results from the old/new recognition task about the feature repetition effects on familiarity. (1) False alarm rates increase as the # of FRFs on new objects increase. (2) Hit rates were not affected by the # of FRFs on the object. (3) The type of feature influences the effect of FRFs only for hits.

The first result showed that if a new object in the test phase had no FRFs, the object was correctly identified as new. Familiarity responses increased linearly as the number of FRFs on the test object increased. In other words, participants classified new objects as old, if these objects had FRFs. The increase in “old” responses with two FRFs was twice the increase with only one FRF. Thus the relation was almost perfectly linear. This supports our hypothesis that familiarity judgements are not based solely on an exact match between the presented stimulus and existing representations. Partial activations of features enabled the classification of new items as old. However, this was true only if the partial activation is caused by frequently repeated features.

Hommel showed that repetition of a set of features while others vary affects performance in a response selection task. Our experiments revealed a similar pattern in a familiarity task. The repeated features caused an increase in false alarm rates. However, we believe that one should not consider the influence of frequently repeated features on familiarity as detrimental to performance. The perceptual system is sensitive to statistical properties of the stimuli (Turk-Browne et al., 2008). This enables extracting crucial information about the environment. Frequently repeated features might indicate regularities which are meaningful to the agent.

Second, feature repetition did not affect the hit rates. Hit rates were in general very high, indicating that participants responded as “old” to actually old objects most of the time. This may indicate that recognition success of the participants was high for the old objects. It means they could successfully represent the objects in the study phase.

Third, we found an interaction effect between feature type and the # of FRFs for hits. This was caused by the relatively small decrease in familiarity scores for objects with 1 FRF of pair 1. Further analysis revealed that this feature was the border feature. This might be due to the difficulty in perceiving or representing the border feature. It is not a basic feature as shape, color and pattern. So, we think that the interaction effect is related with the relatively poor representation of the border feature.

It is important that we obtained different patterns of results for old and new objects. For old objects, the repetition of particular features did not affect familiarity responses significantly. This is reasonable, since if a reliable representation of an object was constructed during the study phase, it should be identified as familiar during the test phase regardless of individual repetitions of the features. However, the opposite is not true, as shown by the increase in false alarm rates with the # of FRFs. Even though the new objects did not have previously constructed representations, they were identified as familiar if they had FRFs. This supports the claim that an exact match between the stored representations and a given stimulus is a sufficient but not a necessary condition for familiarity.

What do the FRFs activate? Do they cause partial activation of the existing representations? The existing theories of categorical representations do not provide answers to these questions. The context model (Medin and Schaffer, 1978) which claims that individual exemplars are stored in memory would not reflect sensitivity of the participants to statistical regularities of the stimuli. On the other hand, prototype theories would not account for the success of participants in recognizing individual objects from the training phase. The hybrid models (Nosofsky, Kruschke & McKinley, 1992) aim to combine the advantages of these two models but this pragmatic approach does not necessarily satisfy biological plausibility. We believe that a more comprehensive theory of perceptual representations, which is not restricted to representation of categories, should be developed, taking recent research on neural populations into account.

From the perspective of synchronization of neuron populations, FRFs can synchronize many representations at once. Why do the "old" responses increase linearly with the # of FRFs on the new object? More FRFs would mean activation/synchronization of more representations. However, since the joint frequency of the FRFs was also high, as well as their individual frequencies, this linear increase might be due to a better match between the stimulus and previously constructed representations. Alternatively, one may claim that FRFs do not activate existing representations, but they themselves constitute individual representations which are easier to activate and which can interfere with perceptual and motor processes in general.

Another thing to note is the effect of feature saliency. Color salience was not homogeneous among the objects because of the patterns we used in the experiment. The color green in dotted objects (where dots are black and other areas are green) were more salient than in objects with diagonal lines (where lines are green and other areas are white). The effect of saliency was reflected in the average familiarity responses for the objects, 0.8 for dotted pattern and 0.5 for diagonal lines pattern. If the FRF was more salient, the feature repetition effect was stronger. This variable will be manipulated in our future experiments.

## Conclusion

In this experiment we tested the feature repetition effect on object familiarity with a continuous old/new recognition task. We found that repetition of particular features increased "old" responses during the test phase for new objects. This increase was linear with the number of repeated features on the object. Saliency of the features also affected familiarity; the more salient the repeated feature was, the more familiar the object was found. We proposed that feature repetition effect might be due to (1) activation of more than one representation constructed during the study phase (2) a separate representation for the repeated features, which has the potential to interfere with several perceptual processes. These findings will guide our efforts in the development of a computational model for the formation and activation of perceptual representations which is currently in progress.

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## References

Ariga, A., Yokosawa, K., & and Ogawa, H. (2007). Object-based attentional selection and awareness of objects. *Visual Cognition, 15(6),* 685-709.

Hanna, A., & Remington, R. (1996). The representation of color and form in long-term memory. *Memory and Cognition, 24(3),* 322-330.

Hommel, B. (1998). Event files: Evidence for automatic integration of stimulus-response episodes. *Visual Cognition, 5,* 183-216.

Hommel, B., & Colzato, L. S. (2009). When an object is more than a binding of its features: Evidence for two mechanisms of visual feature integration. *Visual Cognition, 17(1/2),* 120-140.

Jingling L. & Yeh S. L. (2007). New objects do not capture attention without a top-down setting: Evidence from an inattentional blindness task. *Visual Cognition, 15(6), 661-684.*

Medin, D. L. & Schaffer, M. M. (1978). Context theory of classification learning. *Psychological Review, 85,* 207-238.

Nosofsky, R. M., Kruschke, J. K. & McKinley, S. C. (1992). Combining Exemplar-Based Category Representations and Connectionist Learning Rules. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18(2),* 211-233.

Slotnick, S. D. (2004). Visual memory and visual perception recruit common neural substrates. *Behavioral and Cognitive Neuroscience Reviews, 3,* 207-221.

Turk-Browne, N. B., Isola, P. J., Scholl, B. J., & Treat, T. A. (2008). Multidimensional Visual Statistical Learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34(2),* 399–407.