Visual Search
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Introduction to Visual Search

When you look around the world, only a fraction of the total information available enters your consciousness. This is probably a good thing: our brains would be overwhelmed by incoming stimuli if we had to process everything all at once. For instance, you probably are not aware of your breathing or heart beat until I call your attention to them. The negative side of this equation is that when we are looking for objects in a visual scene, we often have to perform a time-consuming process called visual search, where we choose which objects to attend to and then perhaps perform additional mental processing on the attended items to find what we are looking for.

To see this in action, imagine looking for a friend at a football game. Faces all tend to be very similar, and often require individual inspection. Thus you may find yourself moving your eyes from one face to the next, checking each one to see if it is your friend. Although this is a time-consuming process, there are certain circumstances where search might be fast. For instance, if your friend is African American and the students at your school are mostly Caucasian, your friend might be fairly easy to find in the crowd.

A prevalent view among scientists who study visual search is that attention can be roughly thought of as a spotlight that indicates a region that is receiving extra processing. Items outside the spotlight are processed up to a certain level, but to make complex discriminations we often have to direct attention to a particular location and enable extra mental machinery. So during visual search, an observer would direct this attentional spotlight to different parts of the scene until an item is found.

Cognitive Scientists study the mental processes that underlie visual search using a fairly standard paradigm, called a visual search task. In this task, a number of items are presented on a computer screen, and the subject searches for a known target item. Half of the trials contain a target item mixed in with distractor items, and half of the trials contain just distractor items. The subject in the experiment indicates on each trial whether the target is present or not, and the target-present and target-absent trials are presented in random order. Because this is usually a fairly easy task, scientists often measure how fast the subject responds, which is known as the subject's **reaction time**. Easier search tasks produce faster reaction times.

Within this basic paradigm, a number of possible variations are possible. The most basic change is to vary the number of items on the display (usually there is only one target present, if it is present at all on a particular trial). Different explanations for the processes that underlie search (known as theories or models) make different predictions for what happens to the reaction times as the number of items increases.

The VisualSearch Program
The field of visual search and attention is very large, but there are still lots of unanswered questions, and you can use a java program to address some of them (and even create your own ideas for experiments).

To run the program, access this link:

cognitrn.psych.indiana.edu/busey/VisualSearch/VisualSearchApplet.html
VisualSearchApplet.html

(instructions for installing and running here)

Once you run the program, you will see several pages that introduce visual search. Take a moment to familiarize yourself with the paradigm by doing the example on the first tab, and then click on the 'Properties of Visual Search' and 'Instructions' tabs to see how the program works. These are reproduced below for your reference:

Instructions and Hints

The VisualSearch program is very easy to use, but designing an interesting experiment will take some thinking. On the next two tabs you can select targets and distractors to use in your experiment. You select images from the drop-down menus, and then you can choose whether to colorize them.

Below is an example of one target item that will show an inverted A. If you check the Colorize it button, it will colorize it yellow. You can change the color by clicking on the "Change Color" button. To select a new picture for Target 1, you would click on the arrow on the right to drop down the menu and choose a new picture.

The picture below is just an example; click on the Targets tab above to set up your targets for real. You will also want to set up your distractors in a similar way. For now, leave the targets and distractors at their default settings until you learn the program.

Target 1
☑ Display Target 1
∀ AInverted.jpg ▼
☐ Colorize it CurrentColor Change Color

Once you figure out how to set up targets and distractors, think about answering an interesting research question. Are certain features easier to find than others? Is it easier to find an O in a field of C's, or vice-versa? Why do you think this is?

Your goal should be to address some aspect of how we search through items for a target. What features do we use, and what makes that task easy or hard? Often these questions are answered by measuring performance with many and few distractors to figure out how difficult different search conditions become as more items are added to the display. Click on the Targets tab above to begin your own explorations, although for now leave the settings at their defaults until you learn to use the program.

When you are ready, you can view the target items by clicking on the 'Target's tab to bring up this view:

Target 1
☑ Display Target 1
∀ AInverted.jpg ▼
☐ Colorize it CurrentColor Change Color

Target 2
☐ Display Target 2
— ABar.jpg ▼
☐ Colorize it CurrentColor Change Color

Target 3
☐ Display Target 3
A A.JPG ▼
☐ Colorize it CurrentColor Change Color

Target 4
☐ Display Target 4
∨ AInvertedNoBar.jpg ▼
☐ Colorize it CurrentColor Change Color

Set up your targets here, then click the 'Distractors' tab above to continue

This panel lets you configure up to 4 different targets that will be used in your experiment. The images are actually in a drop-down list that lets you select different pictures to use.

The first time through the experiment, leave the picture for Target 1 at its default setting, the inverted (or upside down) "A." That is the target we will be using for the rest of this tutorial. Click on the Distractor tab to bring up a panel that will let you select some distractors:
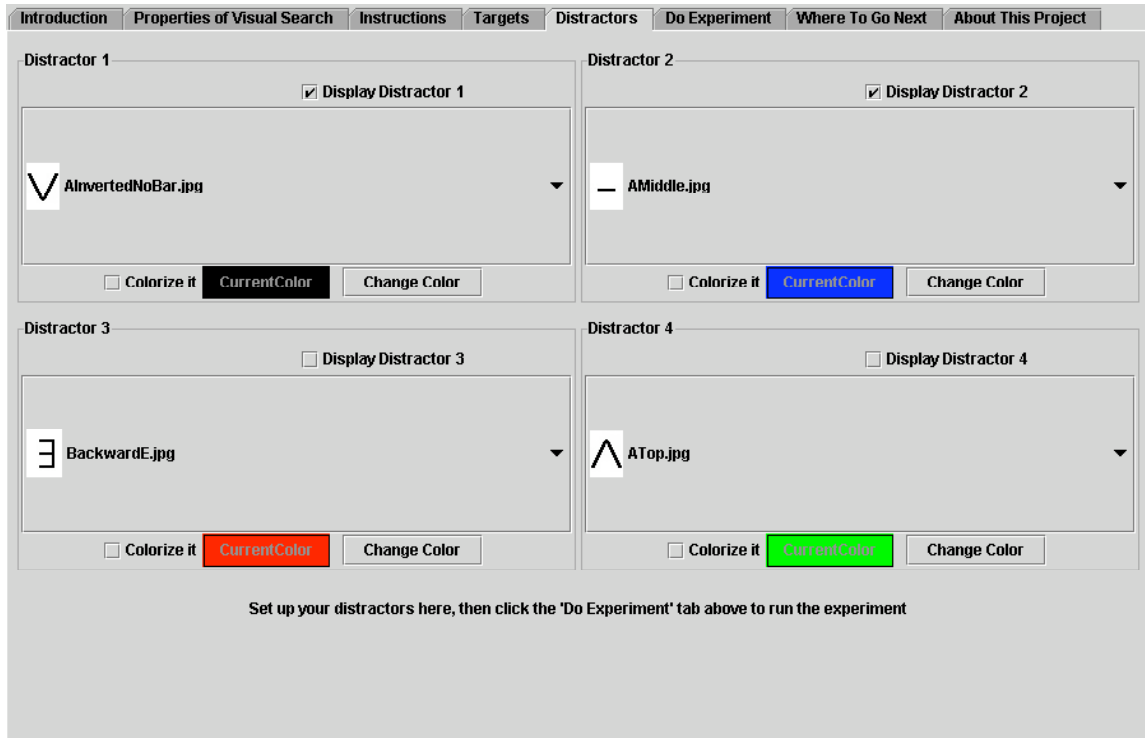
This a similar panel to the targets panel, and is shown configured to display two different types of distractors: the V and the bar. For now, leave these at their defaults and click on the Do Experiment tab to bring up this panel:
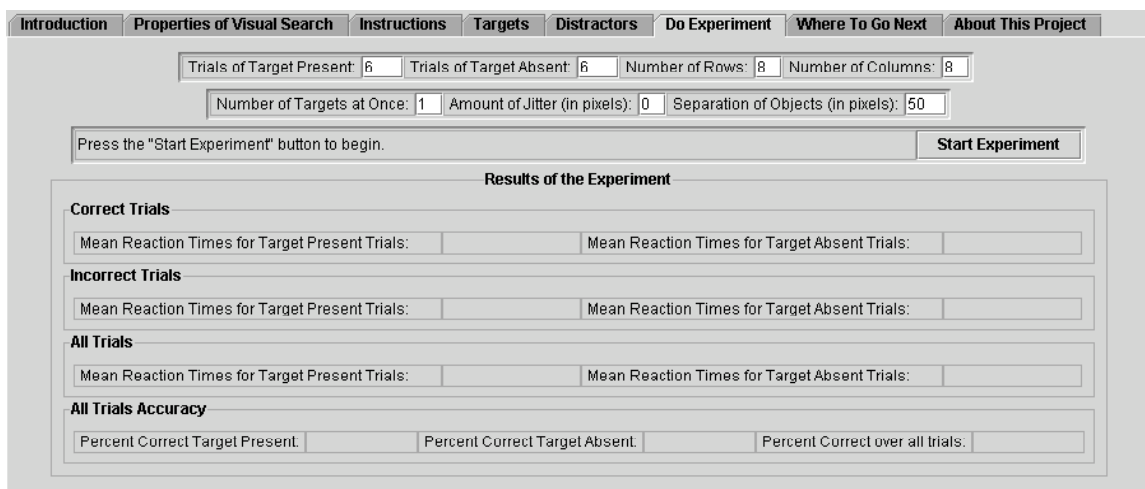
The top two rows set aspects of the experiment, like the number of trials and the size of the display. Leave these options set the way they are and click the Start Experiment button.

Targets   Distractors

∀   V   –
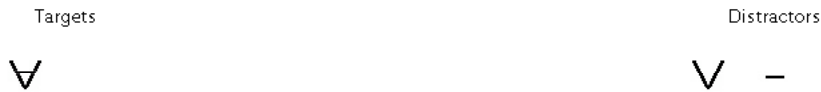
Press 'f' for target present and 'j' for target absent

Press 'f' or 'j' to begin

A new dialog box will open up and show you the targets and distractors that you have chosen for this set of trials:

In this experiment you would be searching for the inverted A and the distractors would be the V and the horizontal bar.

On each trial you will push the 'f' key for target present and the 'j' key for target absent. Put your forefingers on these two keys and press one to start.

Here is a sample trial:

–   –   V   –   –   –   –   –
V   –   V   V   V   –   V   V
V   –   –   –   –   ∀   V   V
V   V   V   –   V   –   V   –
–   V   V   –   V   –   –   –
–   V   V   V   V   –   –   –
V   V   –   V   V   V   –   –
V   –   V   –   V   –   V   –
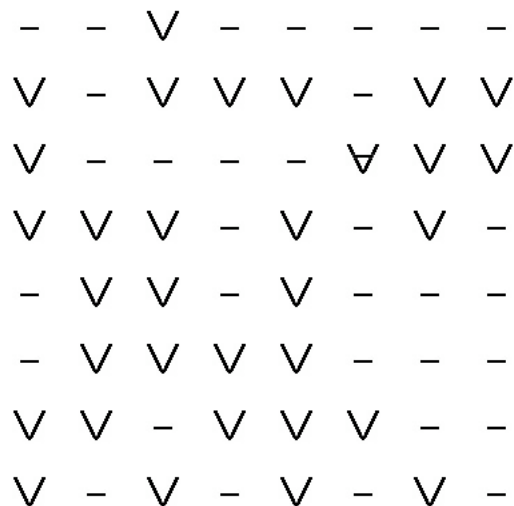
In this trial you would push the 'f' key because the target is present. Remember to respond as fast as you can without making too many mistakes.

When you have finished with all the trials (or if you push the 'quit early' button), the data will be summarized in the table:

| Introduction | Properties of Visual Search | Instructions | Targets | Distractors | Do Experiment | Where To Go Next | About This Project |

Trials of Target Present: 6   Trials of Target Absent: 6   Number of Rows: 8   Number of Columns: 8

Number of Targets at Once: 1   Amount of Jitter (in pixels): 0   Separation of Objects (in pixels): 50

Results are below. Shown are means, with the standard error of the mean in parentheses   **Start Experiment**

Results of the Experiment

Correct Trials

| Mean Reaction Times for Target Present Trials: | 810 (61) | Mean Reaction Times for Target Absent Trials: | 1,089 (118) |

Incorrect Trials

| Mean Reaction Times for Target Present Trials: | 851 (3) | Mean Reaction Times for Target Absent Trials: | 958 (0) |

All Trials

| Mean Reaction Times for Target Present Trials: | 824 (40) | Mean Reaction Times for Target Absent Trials: | 1,067 (99) |

All Trials Accuracy

| Percent Correct Target Present: 0.67 (0.21) | Percent Correct Target Absent: 0.83 (0.17) | Percent Correct over all trials: 0.75 (0.13) |

This table shows the mean reaction times for the target present and target absent trials. Traditionally researchers focus on the mean reaction times for trials with correct responses, and simply check that the accuracy is greater than about .9 (90% correct). The accuracy is lower in the example above because there are so few trials and an incorrect response really hurts overall accuracy. The standard error of the mean is shown in parentheses, which is a rough measure of how consistent the times were with each other.

Interpreting the Data
To get a complete set of data for a particular combination of target and distractor items, you would probably vary the set size and run the experiment several times. To do this, change the number of rows and columns from their current values of 8 and 8 to something smaller like 2 and 2. Re-run the experiment and look at the reaction times. Are they what you expect?

To evaluate your data graphically, plot the reaction times for the target-present and target-absent trials as a function of set size. Separate lines can be used for different conditions. Here is an example:

Sample Data
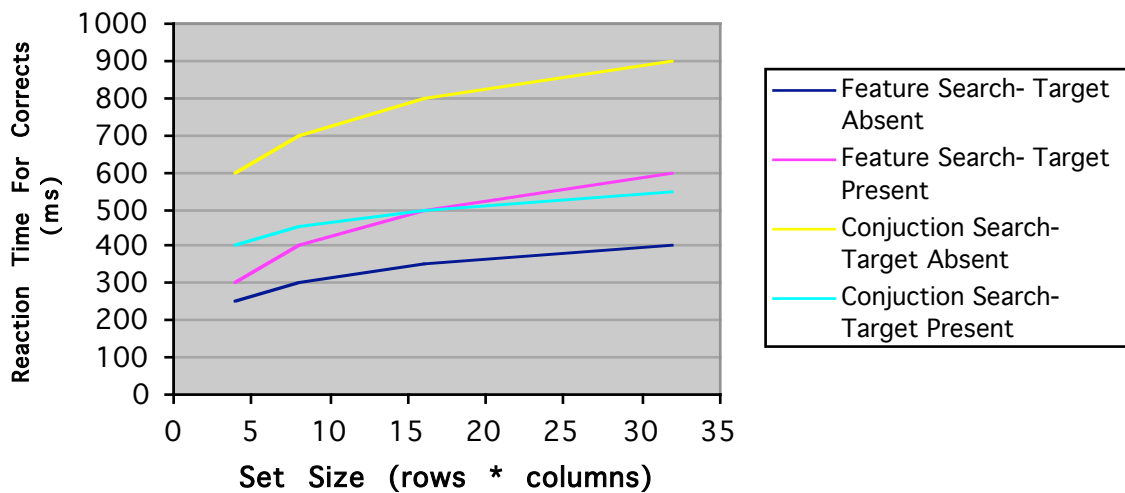
You have done the feature search paradigm in the example above, and the text below describes conjuction searches. Note that only some research questions require looking at multiple set sizes. Often you can pick one set size and compare different types of targets and distractors. Below are some suggestions for designing your own experiments.

Addressing Theoretical Questions
The next step is for you to design your own experiment. You can do this in one of two ways. You can either use the existing images and explore different colors and shape combinations, or you can add your own images. To add your own, you need to run the program as an application and drop your images in the Targets folder which is in the Classes folder. The next time you run the program your images will show up in the list. Remember to save your images as gif or jpeg files and make them no larger than about 50x50 pixels.

To get good data, typically you'll need approximately 40-50 target present and 40-50 target absent trials for each set size. It turns out that the differences between set sizes are fairly small, and reaction times tend to suffer from lots of different factors that make them vary from each other. Factors such as fatigue, vigilance or where your eyes are looking when the trial starts can all influence the reaction times, and so we need more trials to make these factors average out. You'll find in general that the more trials you run the cleaner your data will appear, and it is almost always easier to run more trials than to try to make sense of noisy data.

Before generating your stimuli, it is best to come up with a research question. This is the hardest part of any research program, and also the most important. The best way to learn to create a good research question is to look at examples that are in the literature:

Are people faster to find a Q in a field of O's than to find an O in a field of Q's? If so, why?

Does the similarity between the distractors affect search times? Try to study this without affecting the average similarity between the target and distractors.

Is there an advantage for searching for a letter in a field of non-letters? If so, what does this tell us about the special properties of letters?

Are you faster to identify your face in a field of distractor faces than some other face as the target? If you do this, make sure that the distractor faces have similar properties as the target face. For instance, you wouldn't want your face in color and the distractor faces in black and white. Ideally you would pick two people, take their photographs and put them in the program, and then run both people. Each person's face would be their target item and the other person's face would be the distractor item. See the last tab in the program for instructions on how to add your own images to the program.

What happens if you change the ratio of target present to target absent trials? Right now they are equal. If you had more target absent trials, how would this affect reaction times? How would it affect accuracy for the two conditions? Do you think this means that it affects how quickly you extract information from the display, or reflects something about the decision process?

What is the relation between the set size (the total number of items on the screen at once) and reaction time? Is it the same for both target-present and target absent? Run the experiment at several different set sizes and plot the reaction times for correct trials for both target absent and target present trials.

A conjunctive target search occurs when you need information from two object aspects in order to say "present." For example, if you are looking for a red "X" in a field of red "O"s and blue "X"s then you are performing a conjunctive search. You need to pay attention to both color and shape in order to say "present." With a simple feature search, you only need to pay attention to one aspect in order to say "present." Does the number of distractors influence conjunctive feature searches more or less than simple feature searches? Which of the two searches shows more pronounced practice effects? A practice effect occurs if simply repeating the task improves performance.

In the conjunction search described above, there is a second conjunction target (a blue "O"). Suppose you included both types of conjunction targets in a block of trials. Would this be different than including just one at a time? If so, what would this tell us about multiple target types?

Are all conjunction searches slower than feature searches with the same set of stimuli? A conjunction target is one that is defined by the combination or conjunction of two features. The inverted A in the example above is a conjunction because it is defined as the presence of both distractors at the same time.

Does jitter have any affect on reaction times? Does this depend on the stimulus items that are used? Sometimes individual items can be grouped together to create a pattern or a texture, which is known as a 'field effect' in the literature. Does jitter disrupt this? Does it affect reaction times?

What is the effect of different separations? Can you mathematically describe the relation? Make sure to keep the total number of stimuli constant.

What happens if you have more than one possible target that might show up? Does this change the reaction times? Why do you think this might happen?

What is the effect of having subjects go faster or slower? How does it affect error rates? Does it affect target-present and target-absent trials equally across different set sizes?

Do target present or target absent trials tend to have the higher error rate? What does this tell you about how you make decisions?
As you increase the number of possible targets you are searching for (you can have up to 4 possible target items) does the reaction time get faster or slower? Is this true for both target present and target absent? What does this tell us about the search process?

Is it easier to find a "/" in a field of "l"s, or vice versa? What does this imply about the status of verticality, diagonally, and horizontalness as psychologically useful features?

It would be an interesting, counterintuitive result if you could find a way to make targets less similar to distractors, but harder to search for among the distractors. Can you do it? Here's one starting point. Suppose your distractors are \ and /, and your target is |. What other distractors could you add that would be less similar to the target, thus decreasing the average similarity (which usually helps performance), but actually hurts performance?

The program allows you to have more than one target item appearing on target-present trials. What happens to the reaction times if you increase the number of target items from one to something larger like 4 or 10? Is this what you expect?

Suppose you have only one possible target item. You can either have one type of distractor or up to 4 different types of distractors. Do you think increasing the number of different types of distractors will increase or decrease reaction times?
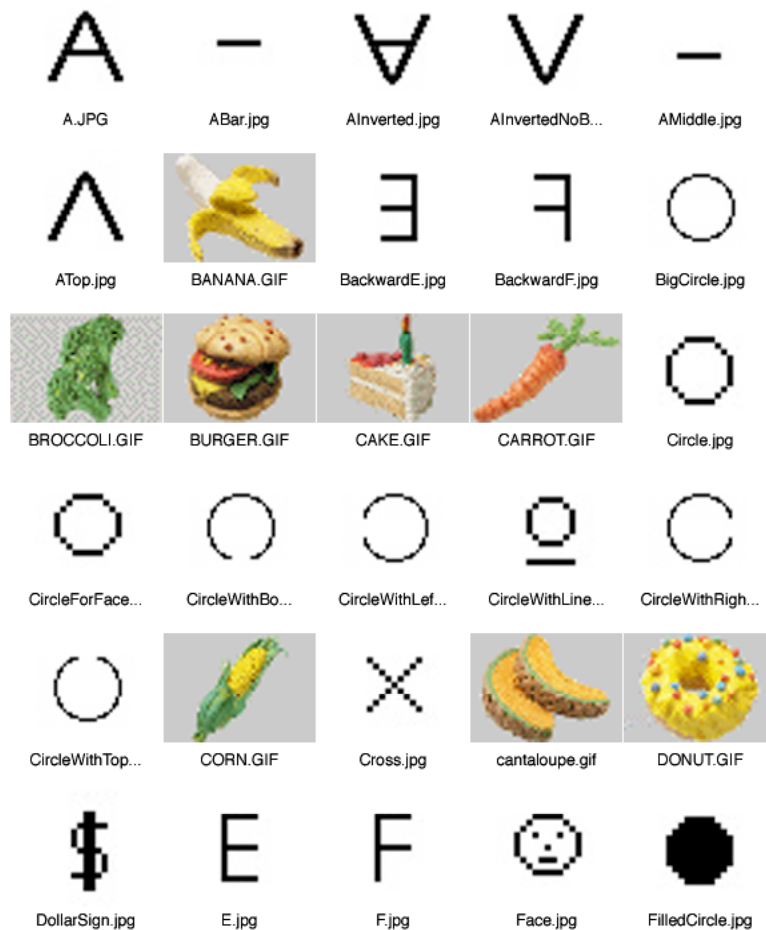
Conclusions
These are only some of the many different research questions that can be addressed using the VisualSearch application. Feel free to create your own research questions, but remember that the overall goal is to understand the search processes in general, not to test specific attributes of your chosen stimuli. So you should frame your question in broad

theoretical terms (e.g. is it easier to find a feature-present target than a feature-absent target) than in terms of your stimuli (is it easier to find a Q among O's than an O among Q's?). Then test your question multiple ways (e.g. is it easier to find an E among F's than an F among E's?).

Stimuli

To help you select stimuli, below is a printout of all the images currently in the database. You can add your own images, or you can choose from this set. Note that stimuli that are designed to go together as a set are often spread out in the list below, and you should think about what an appropriate set should be to test your research question.

A.JPG	ABar.jpg	AInverted.jpg	AInvertedNoB...	AMiddle.jpg

ATop.jpg	BANANA.GIF	BackwardE.jpg	BackwardF.jpg	BigCircle.jpg

BROCCOLI.GIF	BURGER.GIF	CAKE.GIF	CARROT.GIF	Circle.jpg

CircleForFace...	CircleWithBo...	CircleWithLef...	CircleWithLine...	CircleWithRigh...

CircleWithTop...	CORN.GIF	Cross.jpg	cantaloupe.gif	DONUT.GIF

DollarSign.jpg	E.jpg	F.jpg	Face.jpg	FilledCircle.jpg

FiveLines.jpg

FourLines.jpg

FourLinesVer...

FRIES.GIF

FWithLine.jpg

GRAPES.GIF

HighHorizont...

HOTDOG.GIF

HorizontalFor...

ICECREAM.GIF

InternalFaceF...

InvertedCircl...

InvertedF.jpg

InvertedFace....

InvertedFourL...

InvertedInter...

InvertedT.jpg

InvertedTrian...

LeftBottom.jpg

LeftDiagonal.jpg

LeftDiagonal...

LeftRotatedT....

LowerBar.jpg

LowerR.jpg

OneLine.jpg

OpenCircle.jpg

P.JPG

PEACH.GIF

PEAS.GIF

PIE.GIF
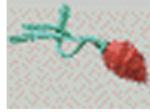
PIZZA.GIF

PLoop.jpg

PlusSign.jpg

R.JPG

RADISH.GIF

RightBottom.jpg

RightDiagona...

RightDiagona...

RightRotated...

RStem.jpg

RVertical.jpg

S.jpg

Square.jpg

softdrink.gif

T.jpg

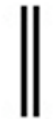ThickVertical...

ThreeLines.jpg

TopLeft.jpg

TopRight.jpg

TREAT.GIF

Triangle.jpg

TwoLines.jpg

UpperBar.jpg

UpperR.jpg

VerticalForPl...

watermelon.gif