FIT Experiment 2021

Final Report

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31 August 2021

Abstract

In this paper we present the results of a conceptual replication from the Feature Integration Theory of Attention (Treisman and Gelade, 1980) based on Experiment 1. The replication resembles the original experiment in the used materials, design, structure, the central hypotheses and the analyzed parameters. It differs in the medium on which it is executed. We use present-day computer based implementation and data analysis. Further, the amount of participants is increased compared to the rather limited study from 1980 in order to find more reliable results. Just as in the original experiment we were able to manifest the so-called pop-out effect in the visual search tasks. The effect occurs when a searched target is sufficiently distinct from the distractor items. This means it differs in exactly one feature. The pop-out effect causes a decrease in the time needed to detect a target in a two-dimensional search space containing a number of distractors. The observed effects are assumed to be the result of a switch from sequential to parallel search for targets that are either unique in colour or shape. Reaction times remain stable for well-distinct targets even in presence of an increasing amount of distractors, while the time to detect targets that share shape and colour with the distractors but in the opposite combination increases with higher numbers of distracting items. This implies that the integration of more than just one feature requires additional processing capacities.

Keywords: feature integration theory, pop out, visual processing, visual search, sequential processing

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In 1980, Treisman & Gelade conducted a series of experiments to provide evidence for their Theory of Feature Integration of Attention in visual processing. This replication study will focus on two aspects of their original work. Treisman and Gelade propose that prior to features of objects being rendered into objects by the brain, the single features of objects are registered in a fast, automatic and parallel fashion over the whole visual field. Yet, the combination and binding of two or more features to eventually form a coherent, recognizable object needs focused selective attention on item after item and is, therefore, slower.
Treisman and Gerade nevertheless were not pioneers in the field of object recognition research. Further, they are not the last ones to propose a model that tries to explain what is going on in our brain when we are processing what we are seeing. Going backwards from 1980, we find Broadbent's filter model of attention. This was proposed by Donald Broadbent in 1958 and functioned as the basis for their experiments. In his theory, Broadbent describes a sort of early selection that enables humans to process information with limited capacity and select information to be processed early.
Also, follow-up studies were conducted, e.g. by Lavie who in his publication claimed that the perceptual load determines the necessity for selective attention (Lavie, 1995).
The circumstance that many researchers who are studying the field of visual search would nowadays claim that the feature integration theory is wrong based on it's dichotomy makes the choice of this experiment, not any less interesting. The reason for that is that no matter what model lies beneath the findings Treisman and Gelade documented back then, the results are still replicable. The theory might be lacking validity in current times yet it still levelled the path for further research and moved the topic of visual search into the focus of psychological experiments. One could therefore say that the feature integration theory might be wrong but highly useful.
In the present study, we replicated the data that Treisman and Gelade collected in their experiment. This enables us to use modern computational resources to lend a different scope to the experiment. And after all, it can always be said that old findings inspire new ones and it is never wrong to go back some steps and learn from the past.
In our analysis, we especially focused on the question if such a thing as a pop-out effect actually exists and if it has an impact on the way we process what we see.
We form our experimental hypotheses based on the original experiment:

1. *Feature Condition:* When a target is distinguishable by one novel feature dimension, identification is mediated by the phenomenon of feature pop-out leading to no significant increase in reaction time concerning an increase of the number of distractors (1, 5, 15, 30).

H_{0F}: reaction time increases respective to an increase in display size in the feature condition. Meaning that the GLM-coefficient of display size is non-zero.

2. *Conjunction Condition:* When a target is distinguishable by two present feature dimensions, identification is facilitated by the sequential processing of objects and their features leading to a linear increase of reaction times concerning the number of distractors (1, 5, 15, 30).
   H_{0C}: reaction time does not increase respective to an increase in display size in the conjunction condition. Meaning that the GLM-coefficient of the interaction term between display size and conjunction condition is zero.

Method

Participants and design

There were 20 participants, of which 15 identify as female and 5 identify as male. The mean age of the females is 24,53, and the mean age of the males is 26,4. We have 20 participants that declared they are right-handed and 0 participants that are left-handed. For participant recruitment a link to the experiment is distributed through an email distributor with all Cognitive Science Students at the University of Osnabrück and through personal connections. The whole experiment is implemented through _magpie and uses several inbuilt functions. The requirement for this experiment was a good understanding of the English language therefore, the participants have a first language demographic distribution of (whatever languages there are in the end). Further requirements are an internet-capable device with a keyboard and a stable internet connection. The experiment will be conducted as a browser-based online keypress task, in which subjects are asked to either press the „L“-key or the „S“-key.

The experiment is designed in a within-subject design, where every participant takes part in every combination of conditions with multiple iterations of the same variable. Thus creates a repeated-measures design. This takes into account the original experimental design as well as the limited number of subjects. In total the experiment takes around 30min.

Materials

The original study by Treisman & Gelade (1980) had their stimuli on white cards. To update this we created our stimuli based on the description in Experiment I of their paper.

There are two conditions “feature” and “conjunction”. The “feature” condition has two sub-conditions which are “shape” and “colour”. So for the “feature” condition, there are 4 possible targets - two for the “shape” and two for the “colour” sub-conditions (Fig. 1). For the “feature” condition there is only one target.

The Target of the “conjunction” Condition is Tgreen, which is made out of the two distractors Tbrown and Xgreen. The “colour” sub condition is made up of the distractor letters but in the colour blue, thus creating the targets Tblue and Xblue.

The targets in the “shape” condition use the letter S but in the same colours as the distractors, making them Sbrown and Sgreen. The two conditions will appear in 4 different display sizes, which differs in the number of elements on the stimuli.
There are either 1, 5, 15, or 30 elements configured. Within each condition, there will be stimuli shown with the expectancy of either “target” or “no target”, this aims for the participants to look for the presence of the target. This is indicated through a key-press. The L-Key is pressed when the target is present. and the S-Key indicates that the target is not shown. For each of the trials the Reaction Time - the time within which the subject detects the target or decides that there is no target visible on the screen indicated through the key-press is recorded.

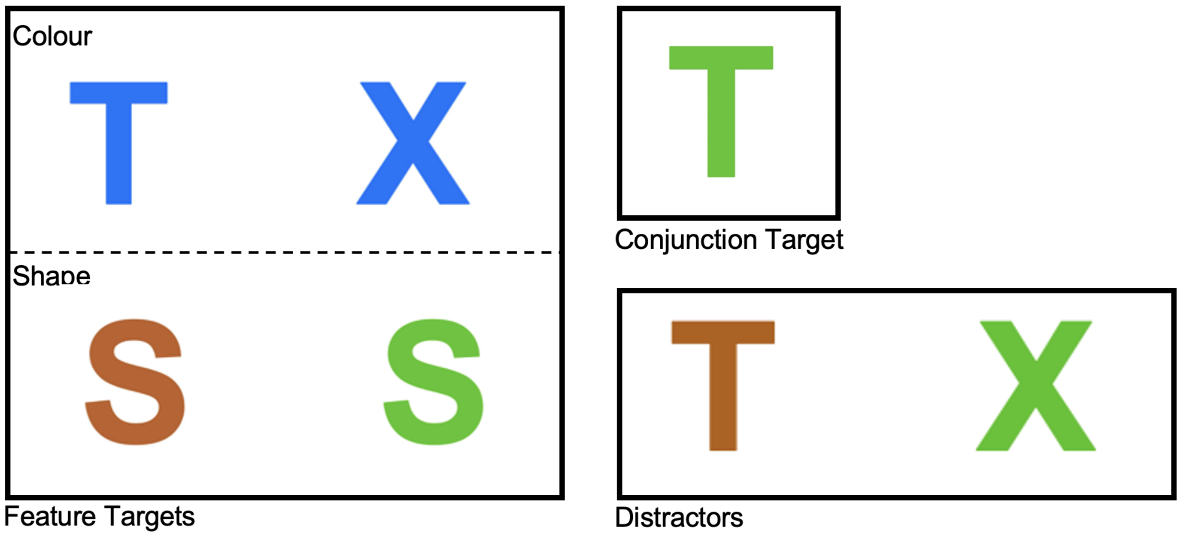

Fig 1: Four different targets for the feature condition (Xblue, Tblue, Sbrown, Sgreen), one target for the conjunction condition (Tgreen) as well as the two distractors (Tbrown, Xgreen)

Procedure

Participants are first exposed to a welcome screen. By pressing a highlighted button they arrive at the general Introduction Screen. This screen provides information on how the condition-dependent introduction screens are to be followed and highlights the focus of speed and accuracy. There are introduction screens for both conditions shown before each block of the respective following condition.
Practice Trails consist of 16 trails (8 in each condition) to get acquainted with the experiment. Main Trials are composed of a total of 384 trials, divided into 6 blocks, consisting of 64 conjunctive and 64 feature trials.
Before each trial, a fixation cross appears in the middle of the screen for 1 sec and is replaced by randomised stimuli. Above the stimuli, there is a reminder of the response keys. After a participant has responded the fixation cross will reappear and feedback if the response was correct and the Reaction Time is given.
During the Trial, a progress bar is shown on the top right of the screen to visualize the progress.

After finishing all the trials there is a short post-experiment questionnaire. We ask for their age, gender, dominant hand, and native language.

Results & Discussion

The data was analyzed by using the means of a general linear model in R mainly consisting of the lme4 package. The whole analysis can be found in the attached Rmd file. The results are bootstrapped with 95% confidence intervals of the reaction time means. This is calculated using the bootstrap() function.

The measured variable is the continuous reaction time within which the participants press the assigned keys on the board. The independent variables are the number of distractors in the search grid (1, 5, 15, 30), the categorical condition (conjunction, feature (shape and color)) and the categorical expected (target/no target) factor of the trial.

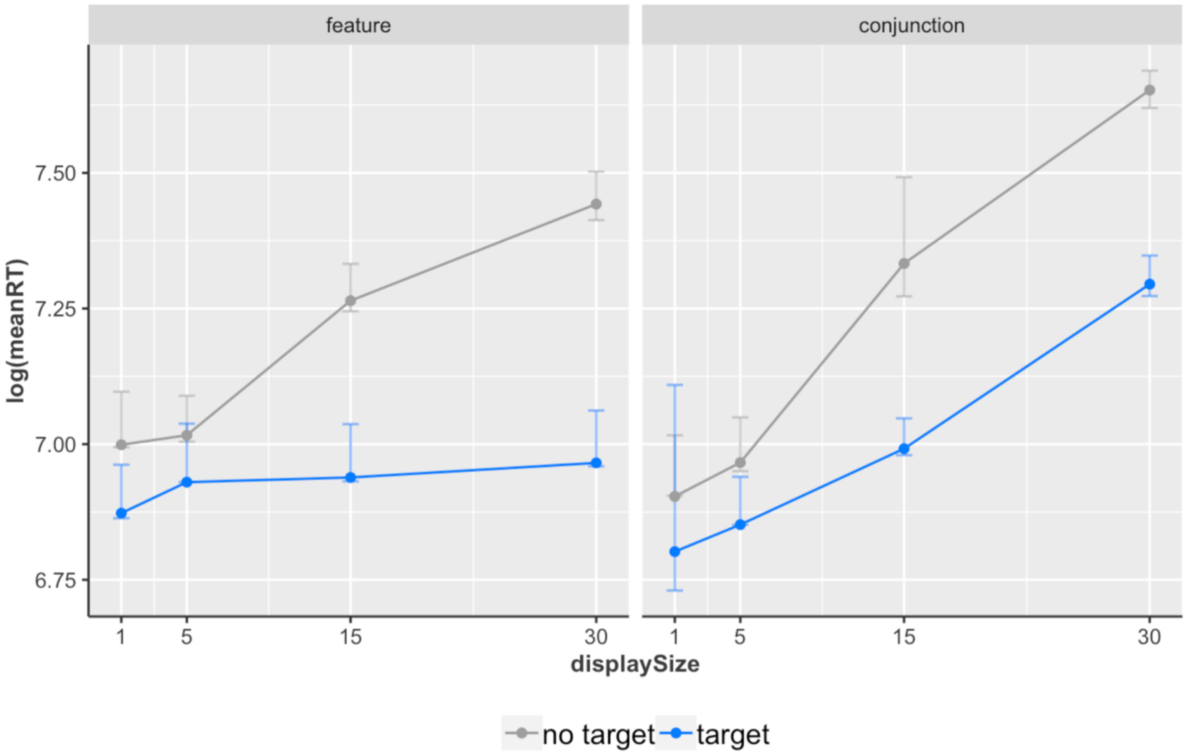

Figure 2: Mean RT scores by stimulus displaySize in conditions feature & conjunction with an N=20

In Figure 2 the mean reaction times is plotted against displaySize whilst showing the confidence intervals as error-bars. It shows the log mean reaction times (log(meanRT) and their 95% confidence intervals (errorbars) with respect to the present displaySize of the stimulus (1, 5, 15 or 30 letters on screen) in both feature and conjunction condition. We chose to transform the reaction time using the log function as reaction times are not normally distributed (leftward skew & left-limited to zero). This decision is backed by Lo & Stevenson (2015). The log transformation is done in this step for ease of comparison and overall consistency since it is used in the general linear regression model. Within both conditions the reaction times including the target (blue) were consistently lower than the ones without the target (grey). Both conditions show a linear increase of reaction time without a target present with a steeper increase in the conjunction condition compared to the feature condition. In the feature condition the increase seems to be almost completely extinguished when a target is present (feature, blue line), while it is still present in the conjunction condition (conjunction, blue line).

With figure 3 we are trying to achieve a very similar plot to Figure 1 in the original Treisman & Gelade Paper we are attempting to replicate here. Here, since this figure is meant to be directly comparable no logarithmic transformation of the RTs was performed.

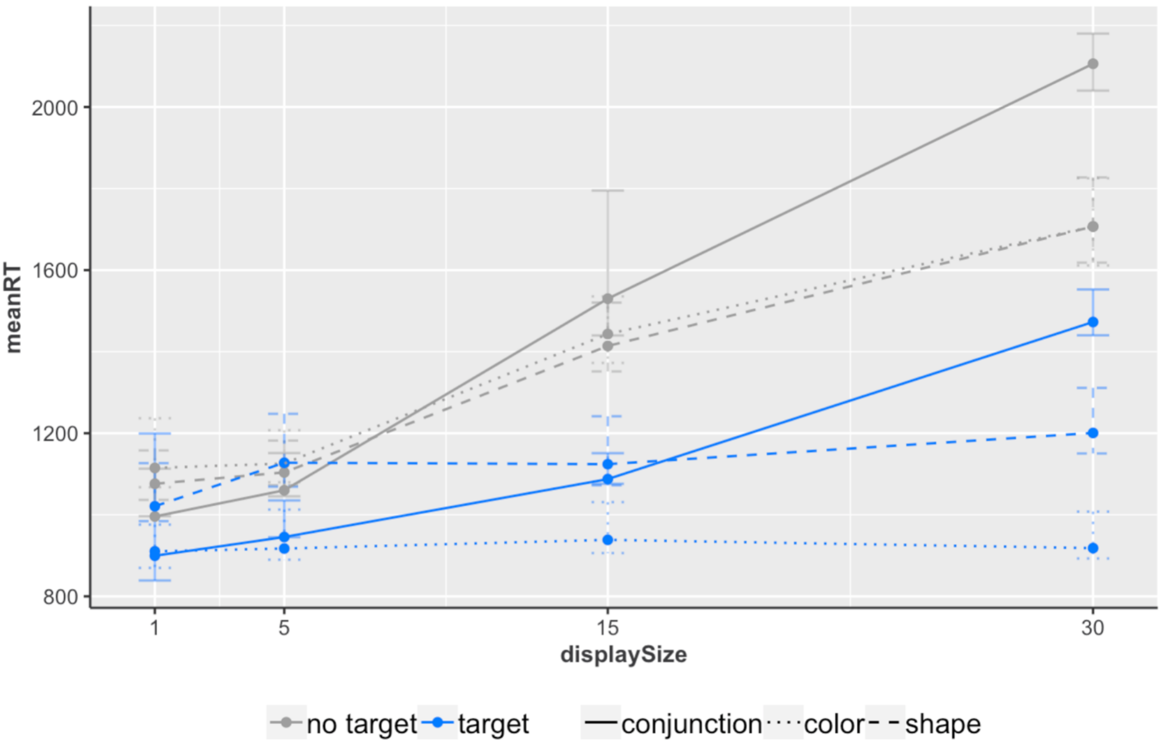

Figure 3: Mean RT scores by stimulus display size in conditions conjunction, color & shape with an N=20

Figure 3 shows the mean reaction times (RT) with respect to the present display size of the stimuli (1, 5, 15 or 30 letters on screen) in both conditions conjunction (solid line) and feature, being subdivided into its sub conditions color & shape (dotted and dashed line respectively). Same as in Figure 2 it is visible that within all conditions the reaction times including the target (blue) were lower than the ones without the target (grey). The steepest increase of reaction time with respect to increasing display size is the one representing the no target conjunction condition. Followed by the closely aligned no target, color and shape conditions as the second and third steepest increase of the same kind. The next line further down (blue, solid) represents the conjunction condition with a target present showing a linear increase in mean reaction time with increasing display size. The following two lines (blue, dashed and dotted) represent the target containing conditions for color and shape subcategories in the feature condition. Both lines, while being on different RT levels, appear parallel to the x-axis with a significant absence of increase compared to the other curves. All of these properties are so far congruent with the findings and the plot of the 1980 Treisman and Gelade paper. The main differences are that our reaction times for display size of 1 are not as densely grouped, while also being higher (all above 800ms here while all below 800ms Gelade & Treisman). In contrast our reaction time maximum lies around 2100ms while theirs is at 2400ms. Next, the color and shape graphs for the target condition (blue, dotted and dashed) are further apart than in the graph of the original research. The same observation can be made with the target containing conjunction condition (blue, solid) and the two non-target color and shape lines (grey, dotted and dashed) which lie closer together in the original paper, with the target condition even superseding the non-target condition. We attribute these differences to altercations in experimental design and execution as well as to measurement technology discrepancies. Generally the differences can be viewed as minor, since the relevant properties like presence and absence of increase of reaction time in our data are fully congruent with the findings from 1980.

Testing the significance we have chosen to run a simple significance test using a general linear model testing the hypothesis that the reaction times are linearly dependent on the condition and displaySize as well as their interaction. Feature Integration Theory states that displaySize should have a bigger influence on RTs in the conjunction condition than in the feature (color, shape) condition. For this we perform a linear regression on the data filtered to the conditions where a target is present. This can be seen in Table 1.

	log(RT)		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	6.81	6.79 – 6.84	**<0.001**
condition [conjunction]	-0.14	-0.18 – -0.11	**<0.001**
displaySize	0.00	0.00 – 0.00	**<0.001**
condition [conjunction] * displaySize	0.02	0.01 – 0.02	**<0.001**
Observations	3840		
R^2	-1.913		

Table 1: Results of the general linear regression model

The outcome is that with the feature condition as our baseline condition the intercept is at 6.81 log(RT) with an influence of 0.00 by increasing the displaySize. Both of these observations are statistically significant based on their p-values below 0.001. In the conjunction condition (mathematically set to 0 in the feature condition, set to 1 in the conjunction condition) the intercept is attenuated by -0.14 and the displaySize now has an effect of increasing log(RT) by 0.02 for every single step increase in displaySize. Both of these observations are statistically significant based on their p-values below 0.001.

These results give us the statistical basis for rejecting H0F and H0C and confirm the Hypothesis. H0F states that the feature conditions coefficient for displaySize is non-zero, which our GLM calculates as zero with statistical significance ($p<0.001$). This leads us to reject this null-hypothesis and embrace our alternative hypothesis that reaction times are not significantly influenced by displaySize in the feature condition. H0C states that the conjunction condition and displaySize interaction term has a coefficient that is zero, which our GLM calculates as 0.02 with statistical significance ($p<0.001$). This leads us to reject this null-hypothesis and embrace our alternative hypothesis that reaction times are significantly influenced by displaySize in the conjunction condition.

Conclusion

We, same as the original study, looked simultaneously at relation between the conditions (feature and conjunction) and at the relation of the subgroups within the feature condition (shape and colour).

The RT within the feature condition showed no significant increase by the amount of distractors and therefore supports our alternative hypothesis.

The RT increased linearly according to the amount of distractors in the conjunction condition; this further supports our alternative hypothesis.

Thus our findings support the findings by Treisman & Gelade (1980). The Pop-Out Effect that occurs in the feature condition due to the single feature change and not a two feature conjunction is further reinforced through our findings.

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