Perceptual Learning vs. Context-Sensitive Retrieval: Why do people judge green lines to be shorter/longer than red lines of the same length? Do they perceive them differently or do they retrieve a biased set of alternatives in their comparison set?

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Abstract

The mechanisms of perceptual learning and contextually sensitive retrieval were recently suggested as possible explanations of the effect of irrelevant information on judgment: the judgment of the same stimulus was reported to depend on its irrelevant characteristics. The reported experiments test the chances for a perceptual learning explanation of the effect. Experiment 1 successfully induces the effect of irrelevant dimension in judgment of line lengths, while Experiment 2, performed immediately after the first experiment, tests the possibility that the perceptual learning mechanisms have led to a “rerepresentation” of the line length depending on its color and thus the participants will actually *see* the red lines as shorter/longer then the red ones. Since Experiment 2 failed to demonstrate any significant difference in perception of the stimulus length depending on its color, the possibility that perceptual learning mechanisms underlie the effect of irrelevant dimension was not empirically supported for the moment.

Introduction

Does irrelevant information influence judgment on a scale? The traditional answer to this question is *NO*, i.e. information that is not required by the target task is considered irrelevant and is neglected by the cognitive processes according to most theories of judgment, including the ones focusing on context sensitivity.

The effect of the irrelevant dimension represents a relatively new research tendency to demonstrate contextual effects on human judgment. Unlike most of the research on context sensitive judgment, the context within this micro-domain was manipulated through the irrelevant-to-the-task stimulus dimension. Suppose that you should judge how tall a person is. You probably do not expect that your judgment may depend on a completely irrelevant stimulus characteristic like the color of the eyes of the target person. Empirical results in this domain, however, suggest that this could be the case, at least under some circumstances.

This paper focuses on the possible mechanism that may underlie the effect of irrelevant information on human judgment and hopefully, to rule out some of the mechanisms that usually were suggested to underlie the effect of interest.

Empirical data on the effect of the irrelevant stimulus dimension

Probably for the first time such an effect of the irrelevant dimension was reported by Marks (1988). Participants in his experiment were asked to rate loudness of tones differing in frequency. To be more precise, the 500Hz tones were low in loudness and the 2 500Hz tones were high in one of the experimental conditions, while in the other - the pairing was reversed. The irrelevant dimension distinguishes the set of stimuli into two subgroups that differ in range, i.e. low and high. As a result, a 500 Hz tone at 70 dB was judged as loud as a 2500 Hz tone at 73 dB. On the contrary, when the 2500 Hz tones were relatively louder to the 500 Hz ones, a 500 Hz sound signal at 70 dB was judged as loud as a 2500Hz tone at 57 dB. These effects were called ´differential context effects´ (DCEs). In essence, DCEs represent a significant contrast effect, i.e. judgments of the same stimuli are shifted away from the context induced by the irrelevant dimension. If the irrelevant dimension joins the stimulus to a set of lower magnitudes, the target stimulus receives a greater rating compared to a situation, where the target stimulus is included in a set of higher magnitudes.

The same direction of the effect of the irrelevant-to-the-task dimension was observed in a series of experiments on judgments of line lengths (Kokinov at all, 2004; Hristova, 2005; Hristova et al., 2005; Hristova and Kokinov, 2006). The context was manipulated through the color of the lines, whose length participants were supposed to judge. Stimulus material comprised a set of 14 lines of different length that were presented either in green or red. Each of the line lengths were presented an equal number of times (7 or 14 times each, depending on the experiment). The frequency of the stimulus presentation was manipulated in such a manner that stimuli sharing the same color form a positively or negatively skewed distribution. As a result, participants´ ratings on a 7-point scale were influenced by the color of the lines and were systematically shifted in the expected direction, i.e. the same lines were overrated when their color was the color of the positively skewed set and underrated, when their color was the color of the negatively skewed set. This effect was called the effect of irrelevant-to-the-task-information and was constantly demonstrated in a number of experiments on judgments of line length that varied the time for stimulus presentation (Hristova & Kokinov, 2006) and the range of stimulus distributions with respect to the color of lines (Hristova, 2005). The same effect was demonstrated in judgment of age, depending on the color of the digits, representing the target's age (Hristova & Kokinov, 2006) and price judgments (Hristova et al., 2005). Overall, the effect was robustly found for the middle-range stimuli (Hristova & Kokinov, 2006; Hristova, 2005) and under some circumstances was successfully found to spread over the whole range of stimulus magnitudes (Hristova, 2005; Hristova et al., 2005). Most of these experiments varied only the skew of the distribution with respect to the irrelevant stimulus color and obtain small though significant effect of irrelevant-to-the-task dimension on judgment of the middle-range stimuli only. However, when irrelevant-to-the task information indicated not only the frequency but also the range of the stimulus distribution, the effect was successfully reproduced over the whole stimulus range. This finding reasonably conform to the Range-Frequency theory, which states that when the range and the frequency principles work together the effect of the stimulus distribution is larger (Parducci, A. 1965, 1974).

Finally, the effect of the irrelevant stimulus dimension was also reported by Goldstone (1995) regarding judgment of the object's color. Participants were asked to reproduce the color of the object on the screen and were influenced by the irrelevant-to-the-task shape of the objects. Basically, their color judgments were assimilated toward the prototype of the category to which the objects belong, depending on their shape. For example, if the object's shape belongs to the category of redder objects, the reproduced color was redder than the reproduced color of an identically colored object that belongs to a different shape, and hence, color category.

In sum, there is a sufficient amount of empirical data, which demonstrates that human judgments depend on the irrelevant stimulus dimension. Unfortunately, these data contradict to each other with respect to the direction of the observed contextual effect and differ on the scale on which the effect was measured. On one hand, Marks and colleagues (Marks, 1988, 1992, 1994, Marks & Warner, 1991; Arieh & Marks, 2002) and Goldstone (1995) used continuous scales to measure contextual effects on judgment, but demonstrated opposite shifts in judgment, i.e. Marks and colleagues always reported contrast, while Goldstone an assimilation effect due to the irrelevant information. On the other hand, Hristova and colleagues (Kokinov et al., 2004; Hristova, 2005; Hristova et al., 2005; Hristova & Kokinov, 2006) used the subjective scale from 1 to 7 in all their experiments and constantly observed a contrast effect from the context of the irrelevant information just like Marks and his colleagues but unlike Goldstone.

One possible explanation of these incompatible results may be hidden in the underlying mechanisms, since different demonstrations of the effect of irrelevant information suggest different cognitive mechanisms to be responsible for the phenomenon of interest. In this paper we will focus on testing the mechanisms that may be responsible for the effect of irrelevant stimulus dimension. More precisely, the study will try to shed light on the question whether a perceptual learning mechanism or a contextually sensitive retrieval mechanism underlies the effect of interest.

The mechanisms that may underlie the effect of irrelevant information

Usually the effect of the irrelevant stimulus dimension is related to perception. For example, Arieh and Marks (2002) argued that the irrelevant stimulus dimension "induce perceptual systems to "recalibrate their relative suprathreshold responsiveness". They demonstrated that visual length perception appeared to be specific to the eye and to the retinal region in which the context was induced. Thus, according to Arieh and Marks (2002) this confirms the hypothesis for early local changes in sensitivity due to the information conveyed by the irrelevant to the task stimulus dimension.

Goldstone (1995, 1998) also assumes that irrelevant information influences the judgment process relatively early in information processing and discuses the possibility for this effect to be a form of perceptual learning phenomena. Goldstone (1998) argues that contextual manipulation of the irrelevant stimulus dimension may cause on-line detectors to be build up, responsible for the effect of interest. Therefore, the same stimulus could be processed from different detectors depending on its irrelevant information. As a consequence the stimulus could be encoded in a different way depending on the detector that had processed it. For example, if the task requires judgment of line lengths and green lines form a positively skewed distribution, while red lines – a negatively skewed one, then according to the perceptual learning hypothesis, the lines would be processed through different detectors depending on their color. The green lines would be perceived through the detector that holds the information about the distribution of all green lines that were seen during the experiment, while the red lines would be perceived through the detector that holds the information about the skew of the red lines. As a consequence, it may happen that the same line length will be judged differently depending on its color because it has been processed through different detectors and thus represented differently (shifted in a particular direction). Overall, the assumption is that detectors change the way stimuli are encoded or "represented" during early perceptual processing of the input information (Goldstone, 1998). According to Goldstone (1998), once such detectors are formed, they may stay the same, at least until similar information is frequently processed, or may disappear with time.

In sum, both the "perceptual recalibration" of Marks and colegues (Marks, 1988, 1992, 1994, Marks & Warner, 1991; Arieh & Marks, 2002) and the perceptual learning mechanism suggested by Goldstone (1998) assume that the effect of the irrelevant dimension results from low-level perceptual "re-representation" of stimuli with respect to their irrelevant characteristic.

Entirely different mechanism for explaining the effect of irrelevant dimension was suggested by the computational model, called JUDGEMAP (Kokinov et al, 2004; Petkov, 2006a; 2006b). JUDGEMAP is based on the cognitive architecture DUAL (Kokinov, 1994). It uses mechanisms basic for analogy-making, like mapping and memory retrieval in modeling of contextual sensitive judgment.

The most important aspect of the JUDGEMAP Model with respect to the current discussion is that the effect of the irrelevant dimension is actually among the model's predictions. JUDGEMAP states that judgment of any particular stimulus is made within a comparison set of other stimuli. This set includes the some recently judged stimuli, some familiar exemplars of the target category and – very important – exemplars which are most *similar* to the target on all dimensions (both relevant and irrelevant to the task). The mechanism underlying this process in JUDGEMAP is spreading activation. As a result, the irrelevant target stimulus information may cause some exemplars to be retrieved in working memory and become part of the comparison set, against which the target stimulus would be judged. Thus, this irrelevant information will indirectly influence the judgment of the target.

Research Aims

This study aims to differentiate between the two mechanisms proposed as underlying the effect of the irrelevant stimulus dimension, i.e. perceptual learning vs. contextually sensitive retrieval. As was already mentioned, if some perceptual learning mechanism was responsible for the effect of irrelevant information, then it should be possible to demonstrate some sort of a "re-representation" of the stimulus magnitude depending on its irrelevant dimension, at least immediately after the judgment task. For example, if during the judgment of line length some detectors for green and red lines were formed, then these detectors should be still there and should be able to "re-represent" the length of green and red lines immediately after the judgment task. In other words, if such detectors were formed during the judgment task, then it should be possible to demonstrate that people saw green and red lines with the same physical length as different. We test this prediction in the following way. Experiment 1 induces the effect of the irrelevant dimension by the frequency of the stimuli that possess a particular color. We replicate the same design, used in a series of previous experiments on judgment of line length (Kokinov, et al., 2004, Hristova & Kokinov, 2006). Experiment 2 was conducted *immediately* after Experiment 1 with the same participants. This experiment was designed to test the prediction of the perceptual learning hypothesis, namely that, stimuli, which already have pushed perceptual system to form particular detectors in order to be able to process them, are "re-represented" by these detectors and hence, are seen in a different way. Experiment 2 applies the procedure of two-alternative forced choice. Participants were shown a pair of green and red lines on each trial and were asked to judge which one is shorter. The critical pair was formed by green and red lines of equal length. It was expected that if people perceive the two lines as equal then their judgments should be divided into 50/50. If their judgments, however, were divided unequally and were biased toward a particular line color, then we could conclude that people "see" the line of a particular color as a shorter one.

In short, this sequence of two experiments was designed to check whether lines with the same length but colored in red or green are perceived by participants as equal in length after the judgment task, where the effect of the irrelevant dimension is usually observed.

Experiment 1

Design

The color of the lines was a within-subject independent variable (varying at 2 levels – green and red). The experimental design was counterbalanced so that the positively and the negatively skewed stimuli to be presented were either in green or in red. The dependent variable was the mean rating of line lengths on a 7-point scale.

Stimuli

14 color lines that vary from 180 pixels to 505 pixels with an increment of 25 pixels were presented 8 times each forming a basic set of 112 trials. Each line was presented either in red or in green. The frequency distribution of green lines in the first experimental group was positively skewed, while that of the red lines – negatively skewed. In the second experimental group the presentation of lines was just the opposite, i.e., red lines formed a positively skewed distribution and green lines formed a negatively skewed one. The frequency of positively and negatively skewed lines is presented in Table 1.

Table 1. Frequency and color of the lines for a block of 112 trials, where the distribution of the lines of color*P* was positively skewed and of the lines of color*N* was negatively skewed.

Lines	***Length in pixels***	Number of lines of *color P*	Number of lines of *color N*
1;2	180;205	7	1
3;4	230;255	6	2
5;6	280;305	5	3
7;8	330;355	4	4
9;10	380;405	3	5
11;12	430;455	2	6
13;14	480;505	1	7

Procedure

Each line was presented horizontally on a grey background in a *random position* on the screen.

Each participant was instructed to judge the length of each line presented on the screen on a seven-point scale: 1- "it is not long at all", …, 7 - "it is very long". The experimenter pressed the button corresponding to the participant's answer and the next line appeared on the screen. No time restrictions have been imposed on the participants.

The experiment was conducted in sound-proof booths and lasted about 15 minutes for each participant.

Participants

24 students (16 female and 8 male) from New Bulgarian University from 19 to 35 years participated in the experiment in order to satisfy a course requirement. There were 12 students in each group.

Results and Discussion

The data was averaged by length (14 lengths) and color (color *P* and color *N*). In this manner we obtained 28 mean judgments (14 lines * 2 colors) for every participant. The color was analyzed as a within-subject factor, while the group was a between-subject factor. The Repeated Measurement Analyses showed a non-significant main effect of the group: F (1, 22) = 0.665, p= 0.424 which means that it does not matter whether the red color or the green one is positively skewed. Thus the results from the two groups are accumulated and we will use *color P* to indicate a positively skewed distribution and *color N* to indicate a negatively skewed distribution in all further analyses.

The main effect of the irrelevant dimension (color *P* vs. color *N*) on rating of the two middle lines was significant, as estimated with the Repeated Measurement Analysis: F (1, 22) =6.095, p=0.022, the effect size (ES) = 0.217. The difference between the mean judgments of positively skewed lines (5.276) and of negatively skewed middle lines (5.141) was 0.135. As in previous experiments (Hristova & Kokinov, 2006; Hristova, 2005), positively skewed middle-length lines were rated higher than negatively skewed middle-length lines despite the fact that they were equal in length (Figure 1).

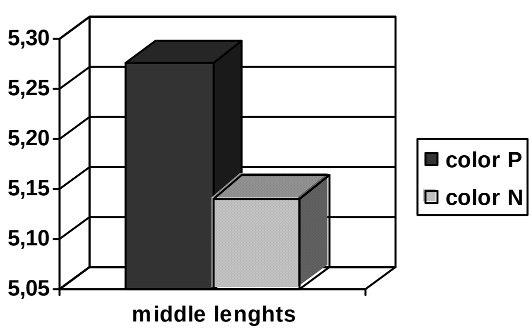

Figure 1. Mean ratings of the *middle line* lengths (line7&8) for each color. The black bar stands for ratings of the positively skewed lines, while the grey-textured bar – for ratings of negatively skewed lines with respect to their color.

The same effect reached marginal significance for the 4 middle lengths, i.e. lines 6, 7, 8 and 9: F (1, 22)=4.009, p=0.058, ES=0.154. The difference between mean judgments of the positively (5.236) and of the negatively (5.152) skewed lines was again in the expected direction, namely, a contrast from the context of the irrelevant to the task color of the lines. Like in most of the previous experiments (Hristova & Kokinov, 2006; Hristova et al., 2005), the effect of the irrelevant dimension was non-significant for all line lengths: F (1, 22) =0.025, p=0.875.

These results are in line with our previous findings demonstrated by experiments following the same design, procedure and stimulus material (Hristova & Kokinov, 2006; Hristova, 2005; Hristova et al., 2005; Kokinov et al., 2004). Therefore, the effect of the irrelevant dimension could be considered as being robust and reliable. Most importantly, however, these results allow us to test the possibility that once the effect of the irrelevant dimension is induced people “see” rather than “judge” line lengths differently.

Experiment2

This experiment was designed to test the prediction of the perceptual learning hypothesis applied to the effect of the irrelevant dimension in judgment of length, namely that once specific detectors for processing particular stimuli are created during a specific task, they, most probably, will re-represent the same stimuli in a subsequent task. To be more precise, if our green and red lines are judged differently because they have been “seen” differently in Experiment 1, then in a subsequent task (Experiment 2) that involves the same lines, they should be re-represented in the same manner as in the first task. We applied the procedure of two-alternative forced choice *before* the judgment task in order to find out whether lines are perceived as being different in length depending on their red or green color and we didn’t found any indication for perceptual illusion (Kokinov et al., 2004). Thus, the effect of the irrelevant dimension could not be due to a perceptual illusion of the line lengths depending on their color but most probably to the specific manipulation of the skew of the line’s distributions with a specific color. We haven’t tried so far, however, to test whether such perceptual illusion is present *after* judgment of line lengths, where lines were presented with particular frequency depending on their irrelevant color. If we find some indications for perceptual illusion *after* the judgment task, then the effect of the irrelevant dimension may be explained by the perceptual learning mechanism that re-represents the length of the lines of a specific color, rather than to a contextually sensitive retrieval.

Design

In the second part of the experiment we use the procedure of the two-alternative forced choice. The independent variable was the difference in the lengths of the left and the right stimulus with 7 levels.

The dependent variable was the number of the left choices made by the participants, i.e. how many times the left line was chosen as the smaller one.

Stimuli

A set of 14 pairs of lines was designed. In each pair, one of the lines was always 270 pixels long[1]. The other varied within the 7 levels of the length - the smallest one was 252 pixels, the largest one was 288 pixels and the increment was 6 pixels (table 2).

[1] The stimuli in both experiments were projected on a 15 inch. Mac computer screen with a resolution 800*600 inches.

Table 2. Stimulus materials used for the two-alternative forced choice procedure.

Intervals		*Difference:* ΔI=I(l) – I(r)
line4; green; 270pixels	Line3; red; 276pixels	1
line4; green; 270pixels	Line2; red; 282 pixels	2
line4; green; 270pixels	Line3; red; 288 pixels	3
line4; green; 270pixels	Line4; red; 270 -pixels	0
line4; green; 270pixels	Line5; Red; 264 pixels	-1
line4; green; 270pixels	Line6; red; 258 pixels	-2
line4; green; 270pixels	Line7; red; 252 pixels	-3

The constant line (270 pixels) was shown half of the times on the left and half of the times on the right. The whole set of 14 pairs was presented 7 times. All 98 pairs were randomly shown to the participants.

Procedure

The two-alternative forced choice procedure was used. Lines were presented on a computer screen in pairs (probes with two intervals). One of the lines in the pairs was always green and didn't vary in length from trial to trial (see Table 2). It was projected on the screen once on the right and once on the left for each pair (14 pairs). The other line in the pair was always red but varied in length. Each pair has ΔI (I (l) – I(r)) that represent the difference in the lengths of the lines that comprise it. All 14 pairs were shown 7 times on a gray background. The whole set of 98 pairs was randomly presented to the participants.

Participants were asked to answer, which is the shorter line– the left one or the right one, even when they find it difficult to reply.

Participants

The same 24 participants were tested immediately after the completion of Experiment 1.

Results and discussion

All choices were divided into 2 groups depending on the skew of green and red lines that participants judged in Experiment 1 and depending on the left line in each trial.

On one hand, if the left line was green and green lines were positively skewed in Experiment 1 or the left line was red and red lines were positively skewed in Experiment 1, the data was coded as belonging to the group "assimilation". Then if participants in group "assimilation" chose predominantly the left line as being the shorter line, their answers could be considered to be biased toward the lines that were positively skewed in Experiment 1, i.e. participants "see" lines of the color of positively skewed lines as smaller than the same lines that possess the color of the negatively skewed set. If we found such results, they could be interpreted in line with Goldstone's hypothesis (1998), that the context of irrelevant information pushes perceptual system to form detectors that assimilate stimulus "representation" toward the "prototype" of the stimuli that share the same irrelevant information.

On other hand, if the left line was green and the green lines were negatively skewed in Experiment 1 or if the left line was red and the red lines were negatively skewed in Experiment 1, the data would be coded as belonging to the group "contrast". If participants choose predominantly the left line as the shorter line in this group, then it will appear that lines of the color of the negatively skewed set in experiment1 are re-represented as smaller than lines of the same length but possessing the color of the positively skewed set. Since such "re-representation" should result in a contrast effect in judgment of line lengths, this group of observations was coded as "contrast" group. Such sort of "re-representation" was suggested by Arien and Marks (2002).

Probit analysis was applied separately on the data of group "assimilation" and group "contrast". In this way we obtained the interception points for every participant in each group, i.e. which is the difference between the left and the right line (ΔI) for every participant such that he/she chooses equally often the left or the right line as being the shorter one. If participants choose 50 times the left line as the shorter one and 50 times the right line as the shorter line when the two lines were equal in length (ΔI =0), then there will be no indication for perceptual illusion. On the other hand, if this result is obtained when ΔI is not equal to 0, then it would be reasonable to assume a perceptual length illusion with respect to a particular line color.

The ratio between the intercept for each participant and the intercept's standard error was compared between the "assimilation" and "contrast" groups by the Paired Samples T-Test. This Statistics doesn't reveal a significant difference between the choices made in the two groups: $t(23)=0.426$, $p=0.674$. The mean difference between the two groups was 0.389, Std.Deviation = 4.481 and the 95% Confidence Interval of this difference was [-1.5027; 2.2815]. This result does not support the claim that the perceptual learning mechanism underlies the effect of the irrelevant dimension since we didn't find any indication for perceptual length illusion after the judgment task, where, as usual, the discussed effect was found.

We wanted, however, to process our data further in order to be able to say what was the scope of the proposed "re-representation" in pixels that was found, though non-significantly, in our data. That is why, the lower and the upper bound of the received 95% Confidence Interval were multiplied by the mean standard error of the intercepts in both groups (0.03792) and then by the smallest difference between the left and right line in pixels (i.e., 4 pixels, see table 2). In this manner, we've got a 95% Confidence Interval of difference between group "assimilation" and group "contrast" in pixels: [-0.2279; 0.3440]. This additional transformation of the results allows us to say that whatever change in the line "representation" takes place after the effect of the irrelevant dimension was induced, it is between 0 and 0.34 pixels. Thus, even if we assume that some sort of stimulus “re-representation” exists, it seems too small to explain the effect of the irrelevant dimension on judgment.

Conclusion

The reported research focused on the cognitive mechanisms that were recently suggested as underlying the effect of the irrelevant dimension on judgment, namely the perceptual learning mechanism vs. the context-sensitive retrieval. The reported experiments do not find any evidence in favor of the perceptual learning mechanism explanation of the effect of the irrelevant-to-the-task information, since it failed to demonstrate a significant change in a stimulus “representation” with respect to its irrelevant dimension. Thus, up to now, it seems more reasonable to assume that the effect of interest results from context-sensitive retrieval, rather than perceptual learning mechanism, since the former mechanism does not require any sort of temporal or long lasting “re-representation” of stimuli that share the same irrelevant dimension. It should be mentioned, however, that although we didn’t find a significant perceptual illusion of line length due to its color, someone might be able to demonstrate it using another methodology. Therefore this possibility cannot be completely ruled out. Moreover, it’s quite possible that the type of scale (subjective or objective) may mater. Both Marks and colleges and Goldstone use continuous scale and although they received effects in opposite direction they both argue for a kind of perceptual learning mechanism as possibly underplaying the phenomenon of interest. Thus it seems reasonable to test the same hypothesis about stimulus “re-representation” after judgment on a continuous scale.

In conclusion, this study once again demonstrates the effect of the irrelevant dimension in judgment of line length on a subjective scale. Moreover, the dynamic formation of the comparison set postulated by the JUDGEMAP model and the spreading activation mechanism responsible for it, seems for the moment the best candidate for providing an account of this contextual effect of irrelevant information.

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