A Common Mechanism Is Possibly Underlying the Shift in Perceptual and Conceptual Judgment Produced by Irrelevant Information

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Abstract

This paper presents two experiments exploring context effects on human judgment and testing JUDGEMAP's predictions that irrelevant information such as the color of the stimulus can produce a contrast effect with respect to skewed stimuli set to be judged. The first experiment demonstrates the effect on a perceptual judgment task (judging the length of lines which are colored in red and green), while the second experiment demonstrates exactly the same effect on a conceptual judgment task (judging the age of a person when the absolute age is presented by numbers with colored digits – red and green). These results rule out the "recalibration" of the perceptual system explanation. The fact that the same effects were obtained in both cases prompts for a common explanation. JUDGEMAP provides such an explanation: the color is used in retrieving past instances in WM based on the spreading activation mechanism and thus the comparison set becomes biased. The biased comparison set which is then mapped on the scale elements produces a shift in the mean ratings.

Introduction

Suppose someone claims that your judgment of her tallness on a scale may depend on the color of her eyes. Most probably you would consider this to be a strange statement. The color of someone's eyes is certainly *not* a *relevant* dimension in the judgment of tallness. Under certain circumstances, however, the irrelevant information, like the color of the eyes, may actually become critical for the subsequent judgment. This strange statement is to be explored in the current paper.

This paper focuses on the mechanism that may underlie such strange prediction, namely: how irrelevant stimulus dimension may influence judgment. The research aims to discriminate between two possible explanations of the effect of the irrelevant stimulus dimension: (1) low level perceptual recalibration of the sensory system (see Arieh and Marks, 2002 for a review) and (2) contextually sensitive memory retrieval (Kokinov, Hristova, Petkov, 2004). In fact, the experimental work presented in the current paper was inspired by the predictions of the JUDGEMAP Model (Kokinov, Hristova, Petkov, 2004) for contextually sensitive retrieval, which may result in systematic shift in judgments due to the irrelevant information.

Evidence for the effect of irrelevant information

Marks (1988) demonstrates that judgment of loudness may depend on the irrelevant to the task tone frequencies. Participants were asked to judge the loudness of a series of tones between 30 and 85 dB. If relatively low sounds were of 500Hz and relatively high ones, of 2500 Hz, participants judged the loudness of the same sound differently depending on its frequency. 500Hz tones were judged to be louder than the tones of the same sound pressure level but of 2500 Hz frequency. These loudness shifts were called differential context effects (DCEs), since loudness judgment depends differentially on the two contextual (irrelevant) frequencies (Marks, 1988). Evidence for DCEs is reported also in the judgments of length of vertical and horizontal lines (Arieh and Marks, 2002), taste (Rankin and Marks, 1991, 1992), haptic touch (Marks and Armstrong, 1996), olfaction (Rankin and Marks, 2000). This line of research demonstrates a contrast effect in the judgment of a stimulus depending on its irrelevant dimension, i.e. a stimulus judgment is displaced away from the context of the stimuli that share the same irrelevant information.

Arieh and Marks (2002) argue that DCEs originate relatively early in the perceptual stream and are possibly a result of the "recalibration of the supra-threshold responsiveness of the perceptual systems". It was shown that DCEs are spatially specific, i.e. were evident only in locations at which they were induced (Arieh and Marks, 2002; Marks, 1996). For example, visual length perception appeared to be specific to the eye and to the retinal region in which the context was induced (Arieh and Marks, 2002). Thus, according to Arieh and Marks (2002) DCEs reflect a relatively early and local change in perceptual sensitivity.

Goldstone (1995, 1998) also assumes that irrelevant information influences the judgment process relatively early in the information processing and discusses the possibility for context effects to result from perceptually grounded on-line categorization of the stimuli to be judged, i.e. learning/forming categories of stimuli produce a change in the perception of these stimuli. Goldstone (1995) reports a shift in color perception toward the color of similar figures although the shape of figures was an irrelevant-to-the-task characteristic. In general, the effect found in these studies was opposite in direction to the one found by Marks and his colleagues and is essentially an assimilation towards the prototype of the category of stimuli sharing the same irrelevant characteristics. Goldstone (1995, 1998) addresses the possibility that this effect might be a form of perceptual learning.

In sum, both contrast and assimilation effects were demonstrated due to the irrelevant-to-the-task dimension. Marks and colleges (Marks, 1988, 1992, 1994, Marks and Warner, 1991, Arieh and Marks, 2002) always report a contrast effect from context induced by the irrelevant dimension, while Goldstone (1995) reports an assimilation effect of a similar experimental design. Thus, it could be assumed that the influence of the irrelevant dimension is a still quite controversial issue in the field of judgment. It is entirely possible, indeed quite probable that the DCEs (Marks, 1988) and the on-line perceptually grounded assimilation found by Goldstone (1995) interact and even cancel each other out in judgment process.

Moreover, it seems that the effect of irrelevant dimension is quite restricted in scope, in the sense that it has been demonstrated mainly with simple stimuli and has been explained mainly by low level mechanisms. It is still quite doubtful whether this effect could be demonstrated with more complex or even abstract stimuli.

In addition, it is argued that the effect of irrelevant dimension results from an early low level contextually sensitive process (Arieh and Marks, 2002; Goldstone, 1995), i.e. irrelevant information influences the judgment by changing the *perceptual input*, *rather than* the later stages of information processing.

In contrast, the JUDGEMAP (judgment as mapping) model (Kokinov, Hristova, Petkov, 2004) predicts that the effect of irrelevant information is produced by the contextually sensitive retrieval of similar information. The model predicts that because of the spreading activation mechanism underlying retrieval, the irrelevant-to-the-task stimulus dimension may matter. Suppose that we have to rate the tallness of a particular person. Other persons that are similar to that one will tend to be retrieved in the working memory (WM) and form the so called *comparison set*. This means that if the person is a lady, predominantly images of other women will be retrieved and thus, the "tallness" of ladies will be computed based on a comparison set different from that of men. This sounds very intuitive. It has, however, further implications: if the lady is blond, predominantly blond ladies will be retrieved, if the person is a teacher, predominantly teachers will be retrieved, etc. Therefore, even irrelevant to the judgment features like the color of the eyes may take part and influence the tallness judgment based on their contribution to the content of WM.

The most important aspect of the JUDGEMAP model with respect to the current discussion is that the model does not pose any restrictions on the type of stimuli (simple, complex or abstract). Thus JUDGEMAP *predicts* that the irrelevant characteristics may influence judgment since judgment of any particular stimulus is made within a set of other stimuli that include the most recently judged ones, the most familiar exemplars of the target category and the most similar to the target stimuli both in terms of relevant and irrelevant-to-the-task dimension(s). The mechanism underlying this process is the spreading activation mechanism.

JUDGEMAP, however, describes judgment on a discrete scale only. Thus we should bear in mind that the predictions of the model describe only judgment on a predefined discrete scale. Since JUDGEMAP does not give an account of judgment on a continuous scale, the model could not generate any specific prediction on the contextual influence of irrelevant information on the continuous judgment task. That is why whenever we refer to judgment in this paper we mean judgment on a discrete scale.

JUDGEMAP MODEL

JUDGEMAP (Kokinov et al, 2004; Petkov, 2005) is a computational model based on the cognitive architecture DUAL (Kokinov, 1994b, 1994c). It uses mechanisms basic for analogy-making, like mapping and memory retrieval in modeling of the contextual sensitive judgment. In this respect, JUDGEMAP is integrated with the AMBR model (Kokinov, 1994a, Kokinov & Petrov, 2001), which is also based on DUAL cognitive architecture. The main assumptions behind the JUDGEMAP model are that: 1) analogy-making is a fundamental human capability and may be considered, therefore, as a basic mechanism that underlie different cognitive phenomena, like reasoning, decision- making, judgment etc. and 2) the same processes may account for both perceptual and conceptual judgment ("how tall is this person" vs. "how expensive is this good").

JUDGEMAP treats the process of judgment as an analogical mapping between a set of stimuli and a set of ratings (i.e. a mapping that will keep the ordering relations of the sets – better stimuli should receive higher ratings). The set of stimuli (called comparison set) includes the target stimulus and possibly some recently judged stimuli, some familiar exemplars of the judged category and some similar to the target, previously encountered stimuli. The set of ratings represents the scale defined by the particular task. As a rule, the stimuli in the first set can dynamically vary with time – some receive additional activation and enter the set, others, on the contrary, lose activation and fade away. Usually all (or most) of the stimuli in the comparison set receive ratings but, as long as the task is to judge the target one, only its rating is reported. The set of ratings is constant (judgment on a particular scale), however, some of the ratings can be more active than others (favorite numbers or ratings recently used in previous judgments). The mapping between the set of stimuli and the scale values could be partial but there is a pressure preserving the ordering relations between objects and ratings.

Prediction of the JUDGEMAP Model

The effect of the irrelevant dimension is among the specific predictions generated by the JUDGEMAP Model. According to the model, each stimulus that has to be judged elicits in WM a set of exemplars that are similar to the target in both their relevant and irrelevant characteristics. Let us consider, once again, the starting example about the judgment of tallness. If the task is to judge how tall a particular person is on a scale from 1 (he/she is not tall at all) to 7 (he/she is very tall), the model predicts that the activation would spread to exemplars in the long-term memory (LTM) that are similar to the target person. For example, if the person is a man, predominantly men would be elicited in the WM, although the task does not require the judgment of men's tallness. Moreover, even such negligible and indisputably irrelevant characteristics like the color of the person eyes may matter and guide the retrieval of exemplars with similar color of the eyes.

The simplest case would be to study what will happen, if two-dimensional objects are rated along one of their dimensions, while the second irrelevant one is manipulated. Let us assume that the task is to rate the length of line segments that vary in color. In this case it is quite clear that the length is the relevant dimension, while the color is irrelevant.

Let the target stimulus be a red line of certain length. In this case, according to the JUDGEMAP model, we may expect that there will be more red lines in the comparison set – they will be activated through the RED concept, which is shared with the target. On the other hand, if the target stimulus is a green line of the same length, more green lines will become part of the comparison set. Now, if it happens that the known red lines are longer than the known green lines, then the two target stimuli (differing only in color) will be included in different comparison sets and hence judged differently, i.e., the green target would be judged to be longer than the red target of the same length, i.e. a contrast effect will be expected.

This prediction was tested and confirmed by a simulation and a psychological experiment (Kokinov et al, 2004). Both of them manipulate the skew of the distribution of line lengths depending on their color: short lines were presented predominantly in green color, while long lines – in red color, thus forming a positively skewed set of green lines and a negatively skewed set of red lines. The two sets of lines of different color were mixed and randomly presented for judgment on a 7-point scale to the model and human participants. Both the simulation and psychological experiments demonstrated a small though significant effect of the irrelevant-to-the-task color of the lines. The observed difference in ratings of positively and negatively skewed lines was 0.053 for the simulation and 0.046 for the psychological experiment on a 7-point scale. In accordance with the JUDGEMAP's prediction, positively skewed lines were judged higher than negatively skewed ones even though they were equal in length (Kokinov et al, 2004).

Aims of the present research

Although the prediction of the JUDGEMAP model for the influence of the irrelevant-to-the-task stimulus dimension was experimentally confirmed, the found small though significant effect of color upon judgment of the line's lengths may leave some doubt that the effect of the irrelevant dimension was an *accidental* one. The present experiments replicate the previous study using similar design and the same experimental question. Since the effect of the irrelevant-to-the-task color of the lines was negligible in size, experiment 1 aims to replicate it and to increase it, if possible. Experiment 2 tries to shed light on the possible mechanisms that may underlie the shift in judgments due to the irrelevant-to-the-task information, namely: whether the effect of the irrelevant dimension is due to contextually sensitive retrieval of similar to the target stimulus exemplars (Kokinov et al, 2004) or is rather due to some early low-level perceptual changes in the stimulus representation with respect to the stimulus irrelevant characteristics (Arieh and Marks, 2002; Goldstone, 1995). To resolve this issue Experiment 2 uses more abstract stimuli and tests the same predictions about the conceptual judgment. If the same effects were obtained in conceptual judgment, then they could not be due to perceptual processes, and this would be considered as a strong support for the JUDGEMAP's explanation related to the retrieval mechanisms in the formation of the comparison set.

Besides, both experiments explore an additional variable – time, i.e. whether the effect of the irrelevant dimension increases, decreases or is rather independent of the number of trials?[1] In order to test this, in all experiments participants had to judge several times the same skewed stimuli set.

Experiment 1: Judgment of line length

Participants were asked to judge the length of lines that appear always horizontally, but in random positions on the screen. Each line was projected for a very short time on the computer screen - for only 100ms. The subsequent answer did not require a prompt, rather the computer "waited" for the participants' answers. Participants were instructed to press the button when they were sure what rating the target line they wanted to enter.

Method

Design

The within subject independent variables were color (varying at 2 levels) of the lines and time (first, second, and third presentations of the 112 stimulus set). The experimental design was counterbalanced so that the positively and the negatively skewed stimuli to be presented were either in green or in red. In the first experimental group the green lines were positively skewed, while red lines form negatively skewed distribution. In the second experimental group, red lines were positively skewed, while green lines were negatively skewed. 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. Participants rated 3 times the same set of randomly presented 112 trials. Thus, the experiment comprised 336 trials (112 trials for a block $_x$ 3). 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 of the red lines – negatively skewed. In the second experimental group the presentation of lines was just on the opposite, i.e., red lines formed a positively skewed distribution (include relatively short lines) and green lines formed a negatively skewed one

[1] If the effect of the irrelevant dimension is considered as a noise, it seems highly probable that the effect will disappear with increasing the number of trials. Moreover, the assimilation effect of the on-line contextually sensitive categorization that Goldstone (1995) reports, may also decrease the contrast effect of the irrelevant dimension in the course of time, since the assimilation toward perceptually similar objects works against the expected contrast effect in the presented experiments. It could, however, be that the influence of the irrelevant information would increase with time, if participants enriched the range and frequency information about the stimuli set with the number of trials. Then, it is more likely for the judges to become more sensitive to the irrelevant stimulus dimension with the number of trials.

(include relatively long lines). The frequency of the positively and negatively skewed lines is presented in Table 1.

Procedure

Each line was presented horizontally on a gray background in a *random position* on the screen for *100 ms.* The participants were instructed to press a button from 1 to 7 on the keyboard whenever they were sure of their rating. When a participant pressed the button corresponding to his/her answer, the next line appeared on the screen. The lines were presented within *three* blocks with the same range and frequency distribution like the one presented at Table 1.

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

Lines	***Length in pixels***	Number of the lines with *color P* (Positively skewed distribution)	Number of the lines with *color N* (Negatively skewed distribution)
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

The participants were instructed to judge the length of each line presented on the screen on a 7-point scale: where 1-"it is not long at all" and 7-"it is very long".

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

Participants

31 students (17 female and 14 male) from New Bulgarian University participated in the experiment. Participants' age varied between 19 and 31 years. They participated in order to satisfy a course requirement. There were 16 students in group 1 and 15 students in group 2.

Results and Discussion

The data was averaged by item (14 lengths). Each participant had 28 mean judgments (14 lines*2 colors). The color and number of trials were 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, 30) = 0.215, p=0.646 which means that it does not matter whether the red or the green color is positively skewed. Thus, the results from the two groups were accumulated and we 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 middle lines was significant, as estimated with the Repeated Measurement Analysis: F (1, 30) =4.400, p=0.045, the effect size (ES) = 0.132. The difference between the mean judgment of positively skewed lines (5.01) and the mean judgment of negatively skewed lines (4.92) was 0.09. 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).

The Repeated Measurement Analysis did not show a significant main effect of color and of number of trials on the mean ratings of all 14 lines (color: F (1, 30) =0.070, p=0.793; number of trials: F (2,30) = 1.354, p= 0.266). The effect of the skewed distribution with respect to lines' color appeared not strong enough to transfer from the middle-sized lines toward all other target lines. This differential effect is coherent with an estimation of the predicted size of the effect based on Parducci's Range-Frequency theory (Parducci, 1965, 1974).

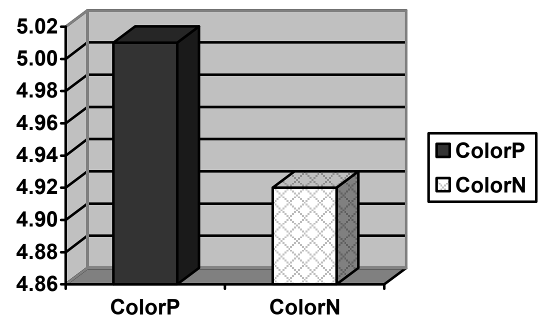

Figure 1. Mean ratings of the *middle line* lengths (line7&8) for each color. The black bar stands for ratings of the positively skewed lines with respect to their color, while gray-textured bar – for negatively skewed lines with respect to their color.

The difference between the ratings of the red and green colored lines is roughly the same as in the previous experiment (Kokinov et al, 2004) – it slightly increased from 0.046 to 0.09 in the current experiment. Thus, although the effect was replicated, it did not increase significantly under time pressure. The replication means that the previously obtained data could not be incidental. At the same time the mechanism responsible for that effect can still be two-fold: perceptual recalibration or memory retrieval.

Experiment 2: Judgment of Age

The goal of this experiment was to differentiate the source of the effect, i.e. whether the effect of the irrelevant-to-the-task dimension is comparable to the effect of sensory adaptation (Arieh and Marks, 2002) or memory retrieval as postulated by JUDGEMAP. The stimuli used in this experiment are rather abstract – they are numbers – and the task is of conceptual judgment (how old is someone of 35 years of age) rather than perceptual judgment (how old is the person on this photograph). Thus, if there is an effect of the color in which the digits are presented, it cannot be attributed to the calibration process of the perceptual system as in other experiments on judgment of lines' length, loudness of tones, taste or touching (Arieh and Marks, 2002). It is difficult to argue that judgment of men's age based on digits, which stand for their absolute age in years may "induce the perceptual system to recalibrate their relative supra-threshold responsiveness" (Arieh and Marks, 2002, p.478). Thus, if the same contrast effect of color was obtained, this would be considered an argument in favor of the JUDGEMAP's explanation: namely, the red-colored digits retrieve more numbers represented with red-colored digits based on the spreading activation mechanism and hence form a biased set of comparison in the WM.

Method

Design

As in the previous experiment, color (i.e., green and red) and number of trials (first and second block of 112 presentations) were within–subject variables in this study. The group counterbalanced age and color: group 1 judged the age of small positively skewed red numbers and high negatively skewed green numbers. The dependent variable was the participant's mean rating for each age depending on the digit's color.

Stimuli

A set of 14 ages was designed. The lowest age was 10 years, the highest age was 75 years, and the increment was 5 years. As in the previous experiment, the ages were presented with uneven frequency depending on the digit's color. The frequency of the stimulus distribution depending on stimulus color is presented in Table 2.

Table 2. Frequency of stimulus distribution depending on the irrelevant-to-the-task color of the digits.

Age category	The digits **representin g** the target age	Frequency distribution of the ages with color P	Frequency distribution of the ages with color N
1;2	10;15	7	1
3;4	20;25	6	2
5;6	30;35	5	3
7;8	40;45	4	4
9;10	50;55	3	5
11;12	60;65	2	6
13;14	70;75	1	7

Procedure

The stimuli were presented for judgment one by one at the center of the computer screen. The background was gray. Stimuli were randomly presented within 2 blocks with the same stimulus range and frequency. The participants rated twice the set of the randomly presented 112 trials described in Table 2.

Judgments were required on a 7-point scale. Each age stayed on a screen until the participant judged it. Then the experimenter registers the respondents' rating and changes the slide manually. The duration of the experiment was 15 minutes.

Participants

41 students (29 female and 12 male) at age between 19 and 29 years took part in the experiment for credits. 21 students participated in group 1 and 20 in group 2.

Results and discussion

The data was averaged for each age. The between-subject factor group showed no effect: F (1,39)=1.390, p=0.246. Thus, as in experiment1, the original colors (red and green) were recoded into *colorP* for the positively skewed stimuli and *colorN* for the negatively skewed ones. The positively skewed *middle* ages were ranked higher than the negatively skewed ones with respect to the recoded color (*color P* and *color N*). The effect of color on judgments of ages 40 and 45 years is significant when tested with the Repeated Measurement Statistics: F (1,39)=5,269, p=0.027. The difference between the ratings with different color of the number is 0.06 and is presented at Figure 2. The effect size is ES=0.119. The main effect of the within-subject factor number of trials was non-significant for the middle-range of the stimulus ages (F (1,39)=0.411, p=0.525), i.e. the effect stayed stable with time – neither decreased, nor increased.

Just like in the previous experiment the main effect of color and number of trials was non-significant for the whole range of ages (10years-75 years) (color: F (1,39)=2.990, p=0.092; number of trials: F (1,39)=1.568, p=0.218), i.e. the contrast effect is observed only in the middle of the scale as predicted by Parducci' Range-Frequency theory (Parducci, 1965, 1974).

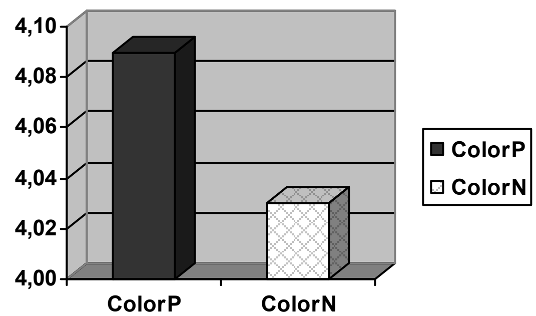

Figure 2. Mean ratings of the middle ages for each color. The black bar stands for the positively skewed lines. The gray textured bar represents the negatively skewed lines.

The results from experiment 2 are consistent with the results obtained from the experiment 1. The effect is similar in direction (contrast), scope (middle magnitudes) and size. The results replicate the previous ones obtained with simple visual stimuli, i.e. lines that differ in color. Moreover, the behavior of the effect seems quite predictable, i.e. the same contextual shift mainly within the middle-sized stimuli at comparable intensity. The most important observation of this experiment is that the effect of the irrelevant dimension was demonstrated within the conceptual judgment task with abstract stimuli. Therefore, it seems difficult, if possible at all, to account for the influence of the irrelevant-to-the-task dimension by referring to the low-level mechanisms like "recalibration" of the perceptual system sensitivity (Marks, 1988, 1992, 1994, Marks and Warner, 1991, Arieh and Marks, 2002). It is quite possible, however, for context to influence judgment at several different levels of information processing. It could be the case that contextually sensitive processes are running in parallel and give raise to different shifts in human judgments (some of which being congruent and others canceling each other out – like the contrast effect obtained in this experiment and the assimilation effect obtained by Goldstone (1995, 1998)).

Conclusion

The two experiments demonstrated a similar in direction, scope and size effect of irrelevant-to-the-task dimension on human perceptual and conceptual judgment. Since the contrast effect of irrelevant information was demonstrated in both cases and with concrete visual and abstract stimuli, it is quite probable that the same mechanism is responsible for these effects. One good candidate is the mechanism of spreading activation postulated by JUDGEMAP as the means for memory retrieval and formation of the comparison set in the WM. The explanation proposed by Marks and collegues (Marks, 1988, 1992, 1994, Marks and Warner, 1991, Arieh and Marks, 2002) that "early local changes in receptive sensitivity" produce this contrast effect seems improbable at least for the conceptual judgment case. Similarly, the perceptual learning mechanisms (Goldstone, 1995, 1998) can not provide an explanation of this conceptual judgment case (in addition, the predicted effect is opposite – JUDGEMAP predicts contrast while the perceptual learning mechanisms predict assimilation). However, it is quite possible for the two mechanisms to work together and in parallel and cancel each other out and that might be the reason why both effects are small. Thus, it is possible to have a contextual effect both at the early and the late stages of information processing (perceptual and memory processes).

These experiments aimed to differentiate between the impact of the retrieval mechanism vs. the impact of the perceptual recalibration mechanism on judgment on a scale. Several issues require further explorations. First, it seems interesting to find out whether irrelevant characteristics can shift the judgment on a continuous scale as well. Second, it is really important to find out the role of categories in our experiments. Although participants in our experiments do not enter the judgment task with preexisting categories like the categories of "green lines" and "red lines" and they are not asked to rate the length of lines within the corresponding category (moreover, the lines are presented in random order and at the end the participants claim they have considered the color of the lines irrelevant and have not used it in the judgment task), it still possible that they construct such categories during the experiment and use them unconsciously.

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