SAME-DIFFERENT DISCRIMINATION: SIMULTANEOUS VERSUS SUCCESSIVE PRESENTATION OF STIMULI

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Abstract: It was found that in the same-different task when a participant has to answer whether several presented stimuli are identical or different, participants can apply two stimuli comparison strategies - holistic or analytic. In the present investigation, it was attempted to assess if the manifestation of such individual differences can depend on the stimuli presentation procedure - successive or simultaneous. Psychophysical experiments of same-different task were carried out in which figures, irregular polygons of various degree of similarity, were presented in pairs simultaneously or successively. In the case of successive presentation of figures, participants were divided into two groups: for the majority of participants, same-different discrimination had an inverse relationship on the degree of similarity - the more two figures were similar, the lower was the accuracy and the longer response time; for the other participants, same-different discrimination did not depend on the similarity of figures. In the case of simultaneous presentation, participants clearly did not differ by the pattern of task performances.

Key words: same-different discrimination, similarity, individual differences

INTRODUCTION

Same-different task, when participants have to answer if several, usually two, presented stimuli are identical or different, is widely used in psychophysical experiments on visual perception. One of the most important factors in these experiments is the similarity of stimuli. Similarity effect is investigated in various visual perception tasks - recognition, identification, detection. Furthermore, many theories explaining visual perception stand upon similarity factor. T. Lachmann and C. van Leeuwen (2004) distinguish two theoretical accounts of performance of same-different discrimination task - analytic and configurational. According to the analytic view, a comparison of stimuli proceeds on a level of stimuli separate features or parameters, such as size, color or shape. Such a view can hardly explain the so-called fast-same effect meaning that response time is shorter for identical than for different stimuli. This effect could be well explained by a configurational, otherwise holistic, view according to which stimuli are compared as undivided units, without segmenting them into separate features. However, the latter view does not explain the response time dependence on the similarity of different stimuli - the more the stimuli are similar, the longer response time is. Researches intending to explain both effects mostly propose models of two processes, holistic and analytic, or parallel and serial (Cooper, 1982; Posner, Mitchell, 1967; Posner 1978; Sternberg, 1998). L.A. Cooper (1982) also pointed out the individual differences in the same-different task performance. He used irregular planar polygons, which differed in small deviations of the vertices of an angle. Initially, the first standard figure was shown for 3 s then, after 1 or 1.5 s of blank interval, the second test figure was displayed which was the same as the standard or differed in a various degree of similarity. L.A. Cooper found that, for the majority of participants, the response time to "different" figures decreased monotonically with increasing dissimilarity between standard and test figure, and the response time to "same" figures was intermediate in duration - longer than for highly dissimilar and shorter than for similar figures. The author termed these subjects analytics. Response time of other participants, named holistics, did not depend on figure's similarity, besides, the mean value of response time was 1.5 times shorter than that of analytics. This author proposes that two strategies of task performance, analytic and holistic, differ in the way in which the visual patterns are encoded and represented in memory. Other researchers found that duration of stimuli retention in short-term memory influences the stimuli comparison process, e.g. D.L. King et al. (2002) demonstrated that with longer retention of the first stimulus in short-term memory the subjective similarity of the second stimulus to the first one grows, therefore, the accuracy of response "different", the proportion of responses "same" to "different", and the response time change. The question is - whether the same-different discrimination differ when stimuli are presented successively or simultaneously, especially keeping in mind that, in the latter case, a short-term memory does not take part directly in task performance. We have found few papers in which successive and simultaneous stimuli presentation procedures are compared directly in the same-different discrimination task. Differences obtained with both procedures are quantitative but not qualitative: shorter response time or higher response accuracy when stimuli are presented successively (King et al., 2002; King, 2002; Larsen et al., 1999), or on the contrary, better task performance when stimuli are presented simultaneously (Dai, Green, 1992; Heeley, Buchanan-Smith, 1992).

This research has a twofold objective: first, to analyze the peculiarities of the same-different discrimination when stimuli are presented simultaneously and successively; second, to reveal qualitative individual differences in both cases. We can expect such differences in the case of successive stimuli presentation on the ground of L.A. Cooper's data, but it would be interesting to know whether qualitative individual differences could be revealed when stimuli are presented simultaneously. In our prior research (Gurčiniene, Šoliunas, 1999) on identification (but not on the same-different discrimination) of two briefly and simultaneously displayed and then masked irregular polygons of different similarity, participants were divided into two groups by the pattern of task performance. Identification accuracy directly depended on polygons' similarity for the one group of participants and did not depend for the other group.

Same-different discrimination of two non-verbal, irregular polygons of different similarity was investigated in two experiments. Stimuli were presented simultaneously in Experiment 1 and successively in Experiment 2.

EXPERIMENT 1

METHOD

Subjects

Forty participants took part in the experiment: 34 (19 women and 15 men) in the first part in which one experimental session was accomplished with each participant and six (three women and three men) in the second part in which every participant took part in three experimental sessions that proceeded on different days. Participants were 21-28 year-old students of Vilnius University and had normal or corrected-to-normal vision. All of them participated for the first time in this kind of research as a part of course requirements. None of them knew the specific purpose of the experiment.

Stimuli

Stimuli were presented on the 17-inch CRT monitor, which was set on 1024 x 768 resolution, 60 Hz vertical refresh frequency and 16-bit color mode. The experiment was controlled by computer program written in Delphi 3 in Windows environment.

Test figures were plane 14-angle polygons composed of connected triangles and squares on the surface of a 3 x 4 matrix (12 square sectors). Area of each polygon was equal to 6.5 sectors. Five sets of figure pairs of different degree of similarity were composed of 12 test figures (Figure 1): pairs of P0 set (overall 12 pairs) consisted of identical figures; pairs of P1 (11 pairs), P2 (13 pairs), P3 (13 pairs), and P4 (13 pairs) sets consisted of figures that differed by 1-2, 3-5, 6-7, and 8-10 sectors, respectively.

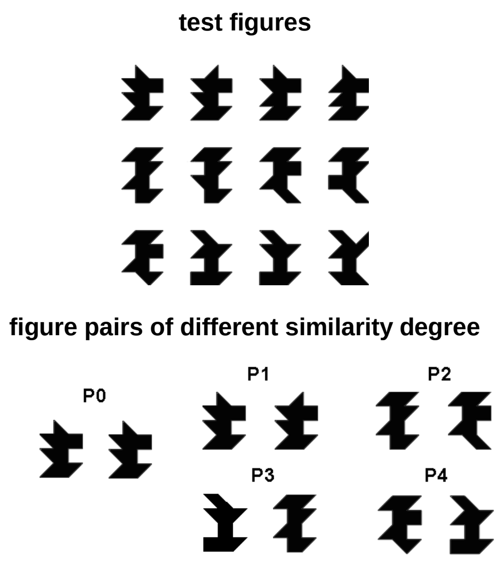

Figure 1. Test figures and examples of figure pairs of different degrees of similarity. Figures in P1, P2, P3, and P4 pairs differ by one, three, six, and eight sectors, respectively.

Figure size on the monitor screen was 1.5 cm x 1.8 cm, distance between two alongside situated figures was 0.5 cm, that is both figures covered 3.5 cm x 1.8 cm or 4° x 2° angular size area. Masking pattern was two 1.5 cm x 1.8 cm rectangulars completely covering both test figures. Test and masking figures were white on a black background.

Sets of figure pairs of different similarity were composed in such a way that a frequency of occurrence of different test figures in each set would be equal as much as possible, though, for objective reasons, some figures occurred more frequently in P1 than in P4 set, and vice versa. Possible influence of the inequality of figure occurrence was evaluated and it was found that it has no determinant effect on the results.

Procedure

Experiment was carried out in a room with a natural daylight background. Participant was sitting about 50 cm from a monitors screen. Before experimental session, each participant performed a practice session of three series of 20 figure pairs seeking to define such exposure time of test figures that identification accuracy would reach 60-80%. In a practice session, figure pairs of all similarity degrees were presented.

Stimuli presentation sequence was as follows: a fixation point (500 ms); a pair of test figures whose exposure duration varied from 67 ms to 350 ms for different participants; masking pattern (500 ms). Participant was asked to press the button *V* on a computer keyboard as soon as he/she decided that the test figures were identical or the button *N* if he/she decided that the test figures were different. Then, an answer button was pressed and after a 200 ms blank interval, the next trial began.

In the experimental session, 184 pairs of test figures were presented (84 pairs of P0 set, 22 pairs of P1 set, and 26 pairs of P2, P3, and P4 sets) in a mixed random order. Each pair in the P1, P2, P3, and P4 sets was repeated twice, counterchanging the left and right figures. The experiment lasted up to 50 min including the practice session.

Response time (RT) and percentage of correct answers were statistically evaluated applying ANOVA, regression analysis, and t-criterion for comparison of means.

RESULTS

Same-different discrimination accuracy and response time averaged for all participants show the same tendency - when dissimilarity of different figures increases the task performance improves, while response time and percentage of correct responses for identical figures have an intermediate value. Analysis of individual data allowed to classify all participants into two groups. The main criterion according to which participants were assigned into the one or the other group was the relation of response time to P1 pairs with response time to P2, P3, and P4 pairs: if the response time was longer for the pairs of P1 set in comparison to the response time for the pairs of the other sets, such participant was assigned to the first group; if this time was shorter, the participant was assigned to the second group. In this way, 25 participants were assigned to the first group and nine to the second group. Response time of the first group of participants increased and accuracy decreased as the similarity of figures increased (Figure 2). Response time did not depend straightly on figure similarity for nine participants, while performance accuracy showed the same tendency as for participants of the first group.

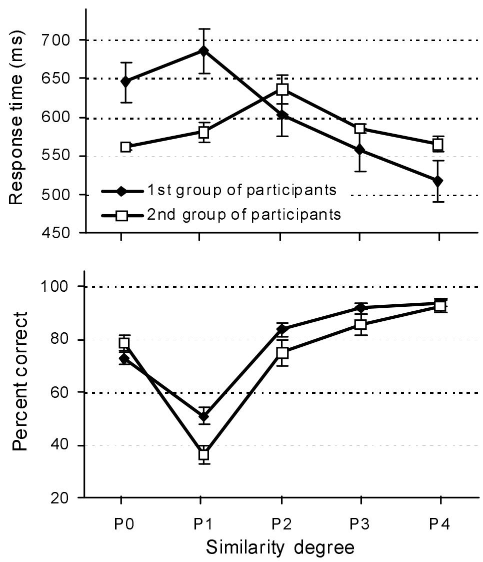

Figure 2. Response time and percent correct of the same-different discrimination of two groups of participants as a function of similarity degree of figure pairs presented simultaneously. The error bars represent ± SE.

Response time data were analyzed using three-way (5 similarity degrees x 2 participant gender x 2 participant groups) ANOVA. Significant main effects of similarity ($F(4,150) = 17.488$, $p < 0.0001$), gender ($F(1,150) = 7.139$, $p < 0.01$), interaction of similarity and groups of participants ($F(4,150) = 16.922$, $p < 0.0001$), and interaction of gender and groups of participants ($F(1,150) = 10.864$, $p < 0.01$) were obtained. Significance of gender factor shows that mean response time for women was longer (652 ms) than for men (551 ms). Significant interaction of similarity and participant group implies that the similarity has different influence on the response time of two participant groups. Regression analysis of RT data of the P1, P2, P3 and P4 figure sets confirms different influence of similarity for participants of two groups: $R = -0.800$, $p < 0.0001$ for the first participant group; $R = -0.0375$, $p = 0.825$ for the second participant group. RT to P1 figures differed significantly from RT to other sets of figure pairs for the second participant group. Statistical analysis implies that the RT for the second participant group does not depend directly on the figures similarity. Significant interaction between gender and participant group shows different influence of gender on the RT in the first and the second participant groups: RT did not differ significantly between women (593 ms) and men (616 ms) in the first group but was longer for women than for men (711 ms vs. 486 ms, $t(43) = 2.774$, $p < 0.01$) in the second group.

Three-way ANOVA of percentage of correct answers shows significant main effects of similarity ($F(4,150) = 85.743$, $p < 0.0001$), participant group ($F(1,150) = 6.882$, $p < 0.01$), interaction of similarity and participant group ($F(4,150) = 4.099$, $p < 0.01$), and interaction of three factors - gender, similarity and participant group ($F(4,150) = 4.299$, $p < 0.01$). Significant interaction of similarity and participant group does not imply different influence of the similarity of figures on the performance accuracy of two groups of participants. As can be seen in Figure 3, the more the figures were similar, the lower the percentage of correct responses was for both groups of participants. Two groups differed only by the total percentage of correct responses: 78.47% for the first group and 73.17% for the second group of participants. This difference, however, should not be treated as an experimental finding because it was determined by an individually defined exposure time of figures (see *Procedure*).

Response time of six participants that performed three experimental sessions (Figure 3) was analyzed by two-way 5 (similarity) x 3 (practice) ANOVA. Significant main effects of similarity ($F(4,75) = 15.894$, $p < 0.0001$) and practice ($F(2,75) = 3.695$, $p = 0.015$) were found. Main effect of practice shows that response time was longer in the first experimental session than in the second and third sessions: 608 ms, 468 ms, and 507 ms, respectively. Insignificant interaction of both factors shows that dependence of response time on the similarity of figures does not change considerably during the practice. Two-way ANOVA of performance accuracy revealed that only the main effect of similarity ($F(4,75) = 64.905$, $p < 0.0001$) was significant. According to the criterion referred to earlier, by which the participants of the first part of experiment were classified into two groups, five participants of the second part of experiment can be assigned to the fist group and one participant to the second group.

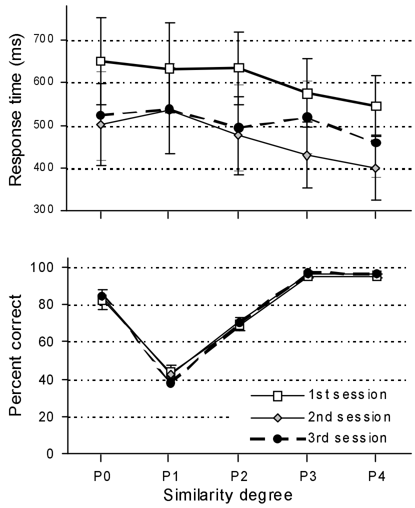

Figure 3. Response time and percent correct of the same-different discrimination as a function of practice and similarity degree of figures pairs presented simultaneously. Averaged results of six participants are presented with ± SE (SE of percent correct are shown only for the first session).

EXPERIMENT 2

METHODS

Subjects

Forty-three students (32 women and 11 men) of Vilnius University participated in the experiment as a part of course requirements. Each participant performed one experimental session. All of them participated for the first time in such a kind of experiment and had normal or corrected-to-normal vision.

Stimuli

The same test figures and the same sets of test figure pairs were used in this experiment, which was conducted, with the Stimscope (© R. Zoontjens, 1997-1999) program in Windows environment. Low contrast figures were gray (luminance value was 247 in a monitor luminance scale 0-255, where 0 corresponds to a black and 255 to a white color of 100 cd/m^2) on a white background. Backward masking was not used.

Procedure

Experimental conditions and the task for the participants were the same as in the first experiment, except for stimuli physical features (as mentioned above) and stimuli presentation sequence. The stimuli sequence was the following: a fixation point (400 ms), a blank interval (250 ms), the first test figure (33 ms - 100 ms), an interstimulus interval (ISI) (500 ms, 1000 ms, or 1500 ms), and the second test figure (33 ms - 100 ms). Exposure duration of test figures was defined individually during practice session as in the first experiment. The ISI between two test figures was 500 ms for all participants in the practice session. Participant had to answer whether both figures were identical or different by pressing either button *V* or button *N*. The next trial began after three s. If the participant did not answer during three s, the wrong answer with no response time was scored. Such cases amounted 1% - 2% of all trials and they were excluded from statistical analysis. In one experimental session, 184 pairs of test figures (84 pairs of P0 set, 22 pairs of P1 set, and 26 pairs of P2, P3, and P4 sets) were presented in a mixed random order. The practice session and the experimental session lasted about 50 min. Because of limited time, each participant performed experimental session with one of three ISI values.

RESULTS

Data of each participant were analyzed separately trying to classify participants into two groups. Classification criterion was the same as in the first experiment. Twenty-eight participants made up the first group, which was characterized by the direct dependence of response time on figures similarity, and 15 participants, whose averaged response time did not depend on figures similarity, formed the second group (Figure 4). To validate distinctive performance patterns for the two groups of participants, three-way (5 similarity degrees x 2 participant groups x 2 participant gender) ANOVA and linear regression analysis of response time to different figures were performed. ANOVA revealed a significant main effect of similarity ($F(4,195) = 16.202$, $p < 0.0001$) and significant interaction of similarity and participant group ($F(4,195) = 8.731$, $p < 0.0001$). Regression analysis confirmed distinction between two groups: R =

-0.797, $p < 0.0001$ for the first group and $R = -0.238$, $p = 0.067$ for the second group of participants. For the participants of the second group, RT to figure pairs of the different sets did not differ significantly, according to Newman-Keuls test. These results lead to the conclusion that the same-different discrimination time of two successively presented figures directly depends on their similarity for the first group and does not depend for the second group of participants. Gender factor was not significant, mean RT was 803 ms for women and 819 ms for men.

Three-way ANOVA (5 similarity degrees x 2 participant groups x 2 participant gender) of accuracy data highlighted significant main effects of similarity ($F(4,195) = 116.806$, $p < 0.0001$) and participant group ($F(1,195) = 24.812$, $p < 0.0001$). Mean percentage of correct responses was 80.72% of the first group and 70.45% of the second group of participants. Both groups of participants showed the same direct dependence of performance accuracy on the similarity of figures.

The dependence of response time and accuracy on an interstimulus interval and the similarity of two successively presented figures are depicted in Figure 5. Two-way ANOVA (3 interstimulus intervals x 5 similarity degrees) of RT revealed significant main effects of similarity ($F(4,200) = 22.311$, $p < 0.0001$) and interstimulus interval ($F(2,200) = 13.885$, $p < 0.0001$) that indicate shorter RT in the case of 500 ms than in the cases of 1000 ms (716 ms vs. 845 ms, $p < 0.0001$ according to Newman-Keuls test) and 1500 ms intervals (716 ms vs. 808 ms, $p < 0.0001$). RT did not differ significantly for the 1000 ms and 1500 ms interstimulus intervals. Insignificant interaction of interstimulus interval and similarity factors indicate that direct RT dependence on the similarity of figures do not change significantly when the time interval between the first and the second test figures gets longer.

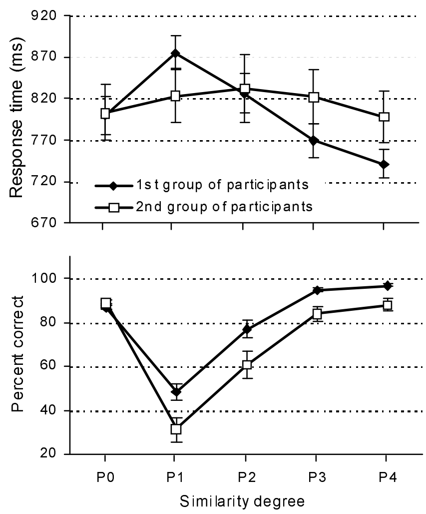

Figure 4. Response time and percent correct of the same-different discrimination of two groups of participants as a function of similarity degree of two figures presented successively. The error bars represent ± SE.

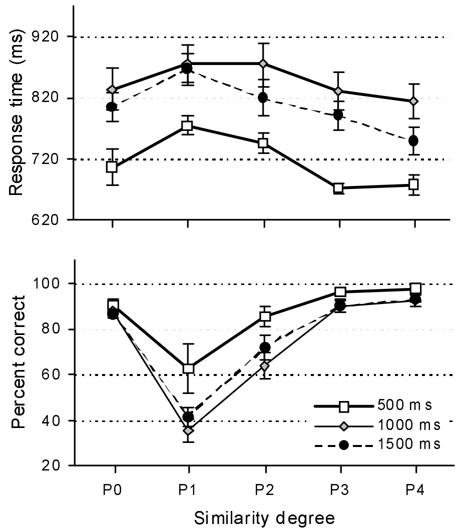

Figure 5. Response time and percent correct of the same-different discrimination as a function of time interval between two successively presented figures and their similarity degree. The error bars represent ± SE.

Two-way ANOVA (5 similarity degrees x 3 interstimulus intervals) of accuracy data revealed significant main effects of similarity ($F(4,200) = 94.012$, $p < 0.0001$) and interstimulus interval ($F(2,200) = 7.737$, $p < 0.001$). Participants discriminated figures more accurately when interstimulus interval was 500 ms than when it was 1000 ms (86.59% vs. 73.95%, $p = 0.019$) or 1500 ms (86.59% vs. 76.61%, $p = 0.034$). Interaction of similarity and interstimulus interval was not significant ($p = 0.061$), and this can be interpreted as if the influence of similarity of figures on the same-different discrimination accuracy does not depend on the duration of time interval between figures.

DISCUSSION

As mentioned in the introduction, L.A. Cooper (1982) found that participants in the same-different discrimination task are divided by the task performance into two groups, termed holistic and analytic participants. The method of our first experiment differed from L.A. Cooper's in a few important aspects: both figures were presented simultaneously and very briefly (60-350 ms) under backward masking conditions. In L.A. Cooper's experiment, the first figure was presented for three s, and the second figure until the participant pressed a response button (400-700 ms). Analyzing our experimental data we also classified our participants into two groups. The first group showed a similar pattern of performance as did L.A. Cooper's analytic participants. In contrast to the holistic group in L.A. Cooper's study, the second group of participants in our first experiment not only did not differ from the first group by averaged response time but the similarity effect was significant for this group as well. Inspecting Figure 2, we can notice an essential difference between the two groups of participants - the response time to P1 figures is shorter than that to P2 figures for the second group, in contrast to the first group of participants. Percentage of correct responses to P1 figures was significantly below chance performance (39.8%, standard error 2.68%, p = 0.015) for the second group of participants, indicating that the most similar figures (P1) appeared as identical for these participants. In such a situation, the response time to P1 figures can be shorter than that to P2 figures because a participant did not distinguish P1 from P0 figures and made a fast but wrong decision that the most similar figures are identical. The shorter RT to P1 and P0 figures for the second group than for the first group of participants whose responses to P1 figures were at chance performance (50.8%, standard error 3.05%, p = 0.800) can be explained by the same reason. Response time to P2, P3 and P4 figure sets shows a similar downtrend for both participant groups. Consequently, we presume that the different pattern of performance of two participant groups in the first experiment was determined by different sensitivity of participants to small deviations from the identity of figures but not by the different task performance strategies, analytic or holistic.

If the participants in the first experiment cannot be clearly classified into two groups by strategies of task performance, the question arises as to whether it is conditioned by a procedure of simultaneous stimuli presentation? The second experiment was conducted to answer this question. Stimuli were presented successively without masking, as in L.A. Cooper's experiment, though stimuli in his study were more complex and their exposure time was considerably longer. Two participant groups were distinguished applying the same criterion as in the first experiment. Participants of the first group showed direct dependence of the same-different discrimination time on the similarity of figures, as did participants of the first group in the first experiment and as analytics in L.A. Cooper's study. No dependence of response time on similarity of figures was found for participants of the second group just as for participants who used the holistic strategy in L.A. Cooper's study, and this pattern of performance distinguishes them from those of the second group of the first experiment. It should be noted that the average response time did not differ significantly for the two groups of participants in our research while in Cooper's study the response time of holistics was 1.5 time shorter than that of analytics. As the same figures and the same task but different procedure of stimuli presentation were used in the first and the second experiments, we suppose that the qualitative difference in the same-different discrimination task performance in the second experiment is determined by the successive procedure of stimuli presentation. In a such situation, the participants that show no effect of figures similarity on response time could compare a second figure with a memory representation of the first figure in a holistic, parallel fashion seeking to verify that two figures are the same. Such a comparison strategy would not involve a search for visual features that distinguish both figures. Subjects whose response time decreases when similarity between two figures decreases could compare a second figure and a memory representation of the first figure in an analytic, self-terminating fashion - the more numerous the features distinguishing two figures, the earlier a difference will be found and the shorter will be the response time.

The results of both our experiments can also support Cooper's hypothesis that different strategies of task performance could be determined by different encoding and representing of stimuli in memory. Subjects should not differ in task performance strategies in a case of simultaneous presentation of figures because such short-term memory does not participate directly in the task performance.

It was suggested (e.g., King et al., 2002), that when stimulus are presented successively, the time interval between the first and the second stimuli is important to similarity evaluation - the longer this interval is, the more similar stimuli appear. Our research supports D.L. King et al.'s findings. In the second experiment, when the time interval between two successively presented figures increased from 500 ms to 1000 ms or 1500 ms, percentage of errors and response time increased as well. The number of errors increased only for different figures, as was the case in D.L. King et al.'s experiment, though the response time got longer not only for different, but also for identical figures. Contrary to D.L. King et al.'s data, the interstimulus interval did not influence the strength of dependence of response time and accuracy on the degree of figures similarity.

Another finding in our research was the relative advantage of the response time of identical over different figures when they were presented successively: 801 ms vs. 808 ms in the case of successive presentation and 623 ms vs. 591 ms ($p = 0.016$) in the case of simultaneous presentation. This result supports P.E. Downing's (2000) suggestion that information stored in short-term memory induces the expectation that the second stimulus will be the same as the first one. Therefore, a subject responds relatively faster to identical than to different stimuli when they are presented successively as compared to the case when they are presented simultaneously.

Different influence of the gender factor was found in the first and the second experiments. The response time was longer for women than for men in the case of simultaneous presentation of stimuli but it did not differ in the case of successive presentation of stimuli. We suppose that such difference could be determined by different requirements on spatial information processing in both cases. It is known, that men perform various spatial perception tasks faster than women do (see e.g., McGee, 1979; Halpern, 1986). In case of simultaneous presentation, when the figures were located at different spatial positions, the same-different discrimination task should require their spatial comparison. In case of successive presentation, when both figures were presented at the same spatial position, same-different discrimination need not involve spatial comparison.

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ROZLIŠOVANIE ROVNAKÝ-ROZDIELNY: SIMULTÁNNE VERZUS SUKCESÍVNE PREZENTOVANIE PODNETOV

A. Šoliúnas, O. Gurčinienė

Súhrn: Zistilo sa, že v úlohe rovnaký-rozdielny, t. j. keď treba odpovedať, či niekoľko prezentovaných podnetov je rovnakých alebo rozdielnych, jednotlivci používajú dve stratégie porovnávania podnetov - holistickú alebo analytickú. Pokúsili sme sa zistiť, či takéto individuálne rozdiely môžu závisieť od spôsobu prezentácie podnetov (sukcesívne alebo simultánne). Uskutočnili sme psychofyzické experimenty s úlohou rovnaký-rozdielny, v ktorých sa simultánne alebo sukcesívne prezentovali v pároch obrazce, nepravidelné mnohouholníky s rôznym stupňom podobnosti. V prípade sukcesívnej prezentácie obrazcov sa jednotlivci rozdelili do dvoch skupín: u väčšiny jednotlivcov rozlišovanie rovnaký-rozdielny inverzne súviselo so stupňom podobnosti - čím boli obrazce podobnejšie, tým boli odpovede nepresnejšie a dlhšie trvali; u ostatných jednotlivcov rozlišovanie rovnaký-rozdielny nezáviselo od podobnosti obrazcov. V prípade simultánnej prezentácie sa výkon jednotlivcov vôbec nelíšil v závislosti od typu úlohy.