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DO COGNITIVE STYLES AFFECT PSYCHOPHYSICAL TASKS PERFORMANCE?

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Abstract

Background. In order to deepen understanding of signal detection/discrimination processes we have to focus on highlighting individual differences in observers' sensory performance due to the contribution of various variables of personality and cognition spheres. The purpose of our study was to test cognitive style factors (augmenting-reducing, levelling-sharpening, flexibility-rigidity of cognitive control, equivalence range, and focusing-scanning) influencing performance of psychophysical tasks. Methods. Ninety participants performed a set of cognitive style tests as well as two psychophysical tasks on visual signal detection ('yes-no') and loudness discrimination ('same-different'). The duration of visual pattern presentation and difference between pairs of auditory stimuli were used to provide task's difficulty level, and therefore the level of uncertainty. Results. Data analysis showed several effects of cognitive styles on psychophysical tasks performance indices, in particular: sensory sensitivity, RT and its stability, and response confidence. According to our results, each style is related to its own benefits and advantages in observer's overall productivity. Furthermore, the contribution of cognitive styles differed depending on task's type and difficulty level. Conclusions. Our results support current findings, considering cognitive styles as playing a regulative role in cognitive activity. Hence, they could be acknowledged as tools, mediating individual strategies, representing different ways of coping with perceptual uncertainty.

Keywords: Cognitive styles, psychophysics, individual differences, signal detection, signal discrimination.

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1. Introduction

Multiple studies showed the effect of subject or personality factors on observer's sensory performance, which nonetheless were rarely taken into consideration. However, it was later acknowledged that contribution of stimulation conditions, or 'stimulus factors', provides only partial explanation of perceiver's behaviour, emphasizing the necessity to consider subject factors as well (Gurler et al., 2015; Siegel, Kelly, 2017; Wilson et al., 2016).

We believe that threshold task performance is associated with a conflict between the need to solve the task successfully and observer's available resources. It has been widely studied in line with resource approach, suggesting that cognitive processes represent the system with limited amount of available cognitive resources. Resources, for their part, are considered as a pool of energy, flexibly distributed during information processing (Epling et al., 2016; Humphreys, Revelle, 1984; Parasuraman et al., 1987; Ralph et al., 2017; Smit et al., 2004; Thomson et al., 2015). Demands and conditions of psychophysical tasks serve as a basis for engaging the methodology of resource approach since they impose several restrictions to observer's available resources.

The stated conflict may be solved in different ways, reflected in the choice of various tools and strategies, regulated, in its turn, by high-level mechanisms of observer's mental activity. We suggest cognitive styles (CS) as one of such regulative mechanisms.

The concept of CS was initially introduced as a result of considering a qualitatively different aspect of human cognitive sphere, referred to individual differences in a way or manner of cognitive functioning, i.e. organizing, representing and processing information (Kozhevnikov et al., 2014; Zhang et al., 2012). In accordance with this approach, same results of solving various types of tasks can be achieved in different ways, such as ways of perceiving and understanding the task, as well as various characteristics of tempo, efficiency and mistakes made (Nosal, 2009). Hence, this is an important factor to examine since CS could provide an explanation of individual variabilities in threshold tasks performance.

2. Problem Statement

There is a large body of research that has been conducted into the role of stimulus factors in observer's performance indices and strategies used, whereas the contribution and weight of individual differences factors is still underestimated in psychophysics. While the final performance can be partially explained by stimulus variables, the study of individual differences is an issue of critical importance.

We would like to highlight the crucial point that psychophysical tasks have to be considered as related to high workload and high perceptual uncertainty. As a result, such task specifities and demands force observer to look for any appropriate compensation strategies, which allow overcoming the distinct deficit of sensory information.

The present tasks cause resource costs due to (1) random and rapid presentation of low-intensive stimulation, (2) monotonous and long-term procedure, (3) successive character of stimuli presentation, (4) spatial uncertainty in localisation of target stimulus. In addition to mentioned above, these vigilance tasks call for engagement of additional effort, reflected in short-term memory and attention allocation resources. Furthermore, observer has to maintain a high vigilance level and sustain high tempo over prolonged period of performing the task.

3. Research Questions

In this study we have endeavoured to address two main issues, referring to the wide psychological context of individual differences role in cognitive tasks solving. First, we were wondering whether differences in sensory performance exist between subjects representing certain CS, and hence, whether CS studies are fruitful avenue in differential psychophysics. The second addressed issue was the following: does the contribution of CS factors change due to variation of task type and level of perceptual uncertainty?

4. Purpose of the Study

The purpose of our study was to test CS factors (augmenting-reducing, levelling-sharpening, flexibility-rigidity of cognitive control, equivalence range, and focusing-scanning) influencing sensory performance indices under different task type (visual signal detection – *YN*, and auditory signal discrimination – *SD* tasks) and levels of perceptual uncertainty.

5. Research Methods

5.1. Participants

A total of 90 participants (28 males and 62 females) with normal or corrected-to-normal vision took part in this experiment.

5.2. Software & Apparatus

The experiment was run on IBM-compatible PC with a clean Windows XP Professional 32 bit operating system, in which all background processes were turned off. The stimuli were presented on a 22” LCD monitor, with a resolution of 1920 × 1080. Participants viewed the monitor from a distance of 60 cm.

Since our tasks suggest short duration of stimulus presentation, the latter was administered through retrace control procedure. RT was registered using a special USB response pad, providing the precision of ± 5 ms.

All experiment tasks were created using ‘Practice MSU’ integrated computer system (UMK Psychology Company, Russia, http://psychosoft.ru).

5.3. Stimuli

In *YN* task stimuli were visual patterns consisting of six letters (Times New Roman font, size 16). The horizontal distance between letters was 35 mm, the vertical one was 55 mm. Three stimuli were used: ‘signal’, ‘noise’, and ‘distractor’ (fig. 01). In *SD* task stimuli were two 1000 Hz tones 200 ms duration with ISI 500 ms. ITI was 2500 ms for both tasks.

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The duration of visual pattern presentation (90 or 60 ms) and difference between pairs of auditory stimuli (2 or 1 dB) were used to provide task's difficulty level, and therefore the level of uncertainty. Each task consisted of five series: (1) introductory – 10 trials, (2) easy training – 30 trials, (3) hard training – 30 trials, (4) main easy – 100 trials, and (5) main hard – 100 trials.

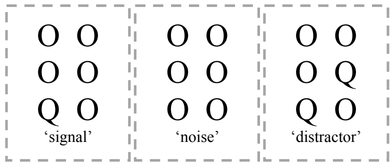

Figure 01. Stimulus patterns, presented in *YN* task

5.4. Procedure

Participants started experimental session with performing two psychophysical tasks. In *YN* task observers were instructed to answer 'yes' when a 'signal' was presented, and answer 'no' in case 'noise' or 'distractor' appeared. In *SD* task observers were asked to assess whether presented pairs of sounds were same or different in loudness. The motor responses were registered by pressing on two different USB pad buttons. After responding participants were asked to assess their response confidence with pressing any button one, two, or three times depending on their confidence level.

Sensory sensitivity (A'), strictness of criterion index (YesRate), RT, RT stability (SDRT) and confidence (Conf) were assessed for each task.

After psychophysical tasks participants performed a set of CS tests:

- Leveling-Sharpening House Test (Santostefano, 1971);
- Stroop Color-Word Interference Test (Stroop, 1935), assessing flexibility-rigidity of cognitive control;
- Object Sorting Test (Gardner et al., 1959), evaluating equivalence range;
- Size Estimation Test (Gardner et al., 1959), appraising focusing-scanning and augmenting-reducing.

6. Findings

One-way ANOVAs showed several significant effects of CS on psychophysical tasks performance indices. The Tables 1-5 present only significant ($p < 0.05$) and quasi-significant ($0.05 < p < 0.1$) effects.

6.1. Augmenting-reducing

Augmenters showed higher accuracy and speed in hard tasks due to their underlying ability to perform under conditions of extremely low stimulation intensity (Larsen, Zarate, 1991). The reducers' strategy to underestimate perceived intensity of incoming stimulation has proved to be less efficient in the hard *SD* task, where the actual stimulation intensity is already too low. Whereas no significant differences

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were found for easy tasks, suggesting that both groups showed the same final efficiency, even though it is associated with different resource costs and strategies used.

6.2. Leveling-sharpening

Sharpeners showed advantages in both accuracy and speed of solving vigilance tasks. We suggest that the possible explanation of found differences between levelers and sharpeners could be provided by individual features of perceiving and remembering the incoming sensory information as well as comparing it to the previous sensory impressions (Gardner et al., 1959; Santostefano, 1971). Since the stimuli in both our tasks were presented successively, not simultaneously, such task conditions impose an extra workload on short-term memory resources (Humphreys, Revelle, 1984; Parasuraman et al., 1987). Thus, sharpeners tend to shape and create more detailed and precise image of perceived sensory stimulation, which have allowed them to solve the tasks quickly and accurately at the same time.

6.3. Flexibility-rigidity of cognitive control

The results indicated that ‘flexible’ subjects showed higher sensory sensitivity in *YN* task, but no significant differences were found in *SD* task. One of the possible contributing factors for this may be the difference in tasks conditions. In particular, the conditions of *YN* task imply the necessity of inhibition of impulsive answer ‘yes’ to stimulus with two target letters (‘distractor’). Thus, in order to accomplish the Stroop task successfully, subject should inhibit the automatic or preponent response, which is related to the inhibition mechanism of executive control functions (Miyake et al., 2000) and corresponds to ‘flexible control’. Since *SD* task do not require inhibition of impulsive answers, both groups reached out to the same level of sensory performance.

Regarding dynamic aspects of task performance, the advantage in RT was shown by subjects with ‘rigidity of cognitive control’. We believe that found differences reflect the depth of information processing. ‘Rigid’ subjects therefore spend less time on response, in contrast to ‘flexible’ ones, who deal with sensory information in depth. Moreover, the features described above could serve as a possible explanation of quasi-significant differences in confidence level. Since ‘rigid’ subjects do not tend to analyse the incoming sensory information in depth, the threshold of evaluating their answer as confident is lower as it is based on fewer stimuli characteristics.

6.4. Equivalence range

Contrary to our initial assumptions, no significant differences in sensory sensitivity were found for this CS. It seems that the tendency to build upon the differences between objects refers to person’s conceptual sphere, i.e. the number of categories in individual mental experience and specifities of intellectual activity in general, rather than in perceptive sphere.

However, the significant differences in confidence level were found for equivalence range. We believe that it is due to ‘narrow’ subjects’ strategy of drawing the attention to differences between stimuli and a more differentiated categorization of sensory experience (Gardner et al., 1959).

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6.5. Focusing-scanning

We suggest that scanners showed advantage in sensory sensitivity in both *YN* tasks due to their underlying ability to allocate attention to various features of visual field, ignoring ones irrelevant to the task demands and goals at the same time (Gardner et al., 1959).

In contrast, focusers showed higher confidence in hard *SD* task. We believe that since focusers tend to draw attention to bright, if not always relevant, features of stimulation, they raise stronger sensory impressions and, in turn, correspondently higher confidence in them.

Table 01. Augmenting-reducing and psychophysical tasks performance

Task	Performance index	Augmenting	Reducing	F	Significance level
Easy YN	YesRate	0.447	0.495	3.494	0.066
Hard YN	RT	0.941	1.039	3.972	0.050
Easy SD	Conf	0.888	0.842	3.327	0.072
Hard SD	A'	0.833	0.771	7.317	0.008

Table 02. Leveling-sharpening and psychophysical tasks performance

Task	Performance index	Leveling	Sharpening	F	Significance level
Easy YN	A'	0.778	0.845	4.603	0.035
	RT	1.192	1.020	6.362	0.014
	SDRT	0.532	0.437	2.791	0.099
Hard YN	A'	0.740	0.819	5.834	0.018
	SDRT	0.447	0.373	3.173	0.079
Hard SD	A'	0.776	0.823	4.170	0.044

Table 03. Flexibility-rigidity of cognitive control and psychophysical tasks performance

Task	Performance index	Flexibility	Rigidity	F	Significance level
Easy YN	A'	0.847	0.768	6.420	0.013
Hard YN	A'	0.811	0.739	4.728	0.033
Easy SD	Conf	0.840	0.883	3.109	0.081
Hard SD	RT	0.915	0.498	4.257	0.042
	Conf	0.796	0.848	3.338	0.071

Table 04. Equivalence range and psychophysical tasks performance

Task	Performance index	Narrow equivalence range	Broad equivalence range	F	Significance level
Easy SD	Conf	0.882	0.830	4.224	0.043
Hard SD	Conf	0.850	0.780	5.847	0.018

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Table 05. Focusing-scanning and psychophysical tasks performance

Task	Performance index	Column Heading	Column Heading	F	Significance level
Easy YN	A'	0.777	0.842	4.309	0.041
Hard YN	A'	0.740	0.814	5.158	0.026
Hard SD	Conf	0.856	0.790	5.511	0.021

7. Conclusion

To conclude, our approach allows considering both subject's activity (CS) and stimulus factors (task type and uncertainty level), determining observer's performance.

The results are crucial in the light of the controversial issue of style value (Zhang et al., 2012). We believe that each style is related to its own benefits and advantages — for instance, either accuracy or speed of performing a task. Neither of style groups should be considered as more or less effective in general; they rather may or may not correspond to the certain conditions and demands in solving the particular cognitive task. However, we stress once again that the same final efficiency could be associated with different resource costs, and furthermore could be achieved in different ways or manners.

We would like to highlight the crucial point that CS should be considered as tools, mediating individual strategies representing different ways of coping with perceptual uncertainty. This understanding is supported by up-to-date findings concerning the role of CS in cognition regulation (Kozhevnikov et al., 2014; Zhang et al., 2012).

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