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И З В Е С Т И Я
Иркутского государственного университета

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Cognitive Style Differences in Detection and Discrimination of Sensory Signals*

A. N. Gusev
Lomonosov Moscow State University, Moscow, Russian Federation

N. N. Volkova
Sberbank, Moscow, Russian Federation

Abstract. The purpose of the study was to test individual differences in sensory sensitivity while performing signal detection and signal discrimination tasks. A total of 98 subjects performed two cognitive style tests on flexibility and rigidity of cognitive control, and focusing and scanning control, as well as two psychophysical tasks on visual signal detection ("yes/no" method) and loudness discrimination ("same/different"), each including two difficulty levels. Task type and difficulty level were considered as stimulation factors, and cognitive styles were considered as individual differences factors. The effects of both cognitive styles along with the effect of their interaction were revealed. 'Flexible' subjects and 'scanners' showed higher sensitivity in signal detection compared to 'rigid' subjects and 'focusers', respectively. Whereas no between-group differences were found in the accuracy of signal discrimination. Thus, we revealed individual differences in sensitivity, driven by cognitive style characteristics on the one hand, and task type on the other.

Keywords: psychophysics; cognitive styles; signal detection; signal discrimination; sensory sensitivity.

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Introduction

A large body of research has contributed to the study of stimulus factors in psychophysical tasks performance. However, it was subsequently recognized that the contribution of stimulation or task conditions provides only partial explanation of the observer's behavior. Nonetheless, the role of the factors, related to the manifestation of individual differences, is still underestimated in psychophysics [Skotnikova, Gusev, 2016; Wackermann, 2014]. In that regard, we highlight the necessity of taking into consideration both stimulation and individual differences factors.

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Therefore we carried out an experiment, in which task type and difficulty level were considered as stimulation factors, and cognitive styles (CS) were considered as individual differences factors. While CS refer to individual differences in cognitive functioning, i.e. in a way or manner of information processing [Kozhevnikov, 2007], they could serve as a fruitful way of explaining individual variabilities in psychophysical tasks performance.

We chose such CS as flexibility-rigidity of cognitive control and focusing-scanning due to their relation to individual differences in control allocation, namely, reactions to stimulus fields containing contradictory cues and attention allocation strategies [Cognitive control. A study … , 1959; Kozhevnikov, 2007]. In order to achieve the diversity in stimulation conditions, we developed two psychophysical tasks: (1) modified visual signal detection 'yes-no' task (YN), and (2) auditory signal discrimination 'same-different' task (SD).

Organization and Research Methods

Participants. A total of 98 participants with normal or corrected-to-normal vision took part in the experiment.

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 the 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 (http://psychosoft.ru).

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'. 'Signal' contained one target letter 'Q' among five letters 'O'; 'noise' consisted of six letters 'O'; 'distractor' contained two target letters 'Q' among four letters 'O'. In SD task stimuli were two 1000 Hz tones 200 ms duration with ISI 500 ms. ITI was 2500 ms for both tasks. 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 a certain difficulty level. Each task consisted of introductory, training and main series, consisted of 10, 30 and 100 trials, respectively.

Procedure. Participants started the experiment 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' was heard. In SD task observers were asked to assess whether the presented pairs of sounds were the same or different in loudness. The motor responses were registered by pressing two different USB pad buttons. We assessed nonparametric sensory sensitivity index A'. After doing psychophysical tasks, the participants performed the following CS tests: Stroop Color-Word Interference Test [Stroop, 1935], assessing flexibility-rigidity of cognitive control, and Size Estimation Test [Cognitive control. A study … , 1959], appraising focusing-scanning. We applied generalized linear models procedure with LSD multiple comparisons test using IBM SPSS Statistics 22. Median split was used in order to reveal two subgroups for each CS.

Results of the Study and Discussion

The statistical analysis of data revealed significant differences in sensitivity between 'flexible' and 'rigid' subjects in both easy (Wald chi-square=6,790; df=1; p=0,009) and hard (Wald chi-square=8,228; df=1; p=0,004) YN tasks. In particular, 'flexible' subjects compared to 'rigid' ones showed clear advantage in accuracy of solving YN tasks (Table 1). Regarding SD task, no significant differences were found (Wald chi-square=0,057; df=1; p=0,811 – easy task; Wald chi-square=0,544; df=1; p=0,461 – hard task).

Table 1

Mean sensitivity indices A' in CS groups

The task difficulty	Flexibility	Rigidity	Focusing	Scanning
Easy YN task	0,837	0,765	0,775	0,831
Hard YN task	0810	0,729	0,744	0,801
Easy SD task	0,900	0,896	0,895	0,901
Hard SD task	0,796	0,811	0,813	0,793

Similar results were obtained for focusing-scanning. Thus, as can be seen in Table 1, 'scanners' showed significantly higher sensitivity in both easy (Wald chi-square=4,068; df=1; p=0,044) and hard (Wald chi-square=4,051; df=1; p=0,044) YN tasks. Whereas no significant between-group differences were found in SD tasks performance (Wald chi-square=0,150; df=1; p=0,699 – easy task; Wald chi-square=0,919; df=1; p=0,338 – hard task).

We analyzed the factor interaction effects as well.

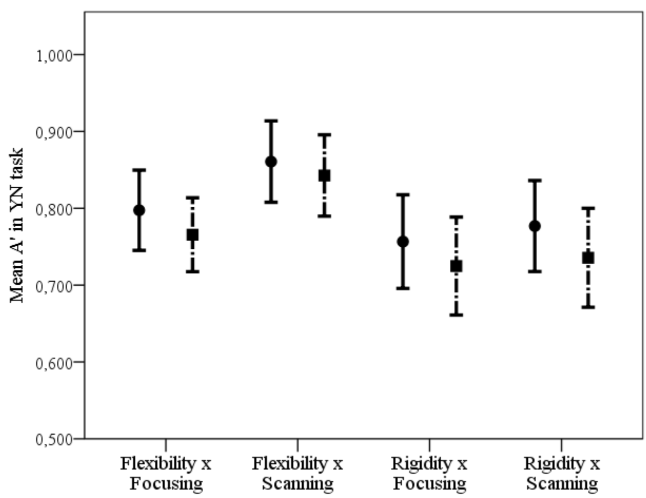

Fig. 1. Mean A' indices in easy (circle, solid line) and hard (square, dashed line) YN tasks

We found statistically significant between-group differences in sensitivity in both easy (Wald chi-square=10,525; df=3; p=0,014) and hard (Wald chi-square=12,771; df=3; p=0,005) YN tasks. As shown in Figure 1, the group of flexible scanners showed distinct advantage in sensitivity compared to three other groups. This is evidenced by multiple comparisons of group values, according to which the group named significantly differs from other three, which, in turn, shows substantially same sensitivity (Table 2).

Table 2

Evaluation of statistical significance of between-group differences in sensitivity index A' (YN task)

Flexibility-Rigidity x Focusing-Scanning		Easy task		Hard task	
		Average difference	Significance	Average difference	Significance
Flexibility x Focusing	Flexibility x Scanning	-0,067	**0,070**	-0,077	**0,042**
Rigidity x Focusing	Flexibility x Focusing	-0,041	0,289	-0,041	0,298
	Flexibility x Scanning	-0,108	**0,002**	-0,118	**0,001**
	Rigidity x Scanning	-0,020	0,614	-0,011	0,792
Rigidity x Scanning	Flexibility x Focusing	-0,021	0,622	-0,030	0,479
	Flexibility x Scanning	-0,088	**0,024**	-0,107	**0,007**

Note. Significant ($p<0,05$) and quasi-significant ($0,05<p<0,1$) differences are highlighted in bold.

However, as can be seen in Figure 2, no significant between-group differences were not found for SD task performance (Wald chi-square=0,442; df=3; p=0,931 – easy task; Wald chi-square=1,304; df=3; p=0,728 – hard task).

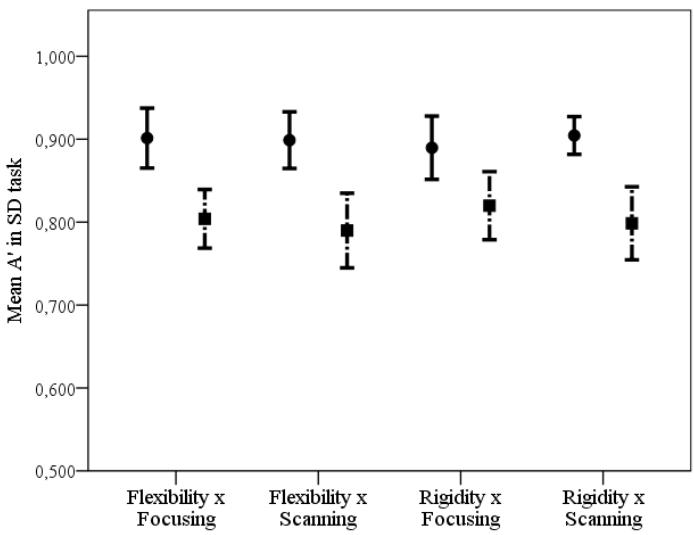

Fig. 2. Mean A' indices in easy (circle, solid line) and hard (square, dashed line) SD tasks

Conclusions

The results indicated that 'flexible' subjects and 'scanners' showed higher sensitivity performing YN task compared to 'rigid' subjects and 'focusers', respectively. Moreover, 'flexible scanners' were found to be the most successful group compared to others. We suggest that it is due to their ability to analyze the incoming stimulation in depth while paying attention to various features of visual field, ignoring those irrelevant to the task requirements, at the same time [Cognitive control. A study … , 1959; Kozhevnikov, 2007].

It is noteworthy that we obtained similar results for both flexibility-rigidity and focusing-scanning CS, as well as their interactions. In particular, significant between-group differences were found only in YN tasks, not in SD ones. We suggest that one of the possible explanations of this finding may be the difference in task conditions. Thus, the procedure of YN task implies the necessity to inhibit automatic impulsive response 'yes' to 'distractor' – the stimulus with two target letters instead of one. Since both 'flexibility' and 'scanning' CS dimensions refer to the inhibition of automatic reactions to irrelevant stimulation [Kozhevnikov, 2007], correspondent groups showed advantage in accuracy of solving YN task. Thus, the successful performing of Stroop and Size estimation tasks includes the need to inhibit automatic responses and pay no attention to irrelevant stimulation features [Cognitive control. A study…, 1959; Kozhevnikov, 2007]. Moreover, the Stroop test, in particular, is related to the inhibition mechanism of executive control functions [The unity and diversity … , 2002]. A SD task, in its turn, does not require the incorporation of such CS resources, and therefore both groups reached the same level of task performance.

Thus, our approach allows considering both individual differences and stimulus factors, determining observer's performance. We found individual differences in psychophysical tasks performance, driven by CS characteristics on the one hand, and a type of the task on the other. We developed the modification of 'yes-no' task that allows 'provoking' the manifestation of CS related to control allocation.

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Когнитивно-стилевые различия как фактор эффективности обнаружения и различения сенсорных сигналов

А. Н. Гусев

Московский государственный университет им. М. В. Ломоносова, г. Москва, Россия

Н. Н. Волкова

ПАО «Сбербанк России», г. Москва, Россия

Аннотация. Цель исследования – оценить вклад когнитивно-стилевых особенностей как важных индивидуально-психологических различий наблюдателей в эффективность решения сенсорных задач по обнаружению и различению зрительных и слуховых сигналов. 98 участников исследования выполняли компьютерные тесты, по результатам которых оценивались когнитивные стили: гибкости – ригидности когнитивного контроля и фокусирующего – сканирующего контроля. Решались две психофизические задачи по обнаружению зрительного сигнала на фоне помех (метод «да – нет») и различению громкости двух тональных сигналов (метод «одинаковые – разные»). Каждая задача включала обнаружение и различение сигналов двух уровней сложности. Тип задачи и ее сложность рассматривались нами как стимульные факторы, а когнитивные стили – как факторы индивидуально-психологических различий наблюдателей. С помощью статистического анализа были обнаружены эффекты влияния обоих когнитивных стилей, а также эффект их межфакторного взаимодействия. Анализ результатов показал, что «флексибильные» наблюдатели и «сканировщики» демонстрируют более высокий уровень сенсорной чувствительности при обнаружении зрительного сигнала по сравнению с «ригидными» и «фокусировщиками». В то же время не было обнаружено межгрупповых различий в точности различения сигналов по громкости. Таким образом, установлено, что, с одной стороны, когнитивно-стилевые особенности определяют различия в сенсорной чувствительности, а с другой – зависят от типа и требований сенсорной задачи.

Ключевые слова: психофизика, когнитивные стили, обнаружение сигнала, различение сигналов, сенсорная чувствительность.

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Гусев Алексей Николаевич
доктор психологических наук, профессор
кафедра психологии личности
Московский государственный
университет имени М. В. Ломоносова
Россия, 119991, Москва,
ул. Ленинские Горы, 1
e-mail: angusev@mail.ru

Gusev Aleksei Nikolaevich
Doctor of Sciences (Psychology), Professor,
Psychology of Personality
Lomonosov Moscow State University
1, Leninskie Gory, Moscow, 119991,
Russian Federation
e-mail: angusev@mail.ru

Волкова Наталия Никитична
менеджер
ПАО «Сбербанк России»
Россия, 117997, Москва, ул. Вавилова, 19
e-mail: n.volkova.psy@gmail.com

Volkova Nataliia Nikitichna
Manager
Sberbank
19, Vavilov st., Moscow,117997,
Russian Federation
e-mail: n.volkova.psy@gmail.com

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