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THE MEASUREMENT OF THE ANALYTICAL STYLE OF INFORMATION PROCESSING. A PRELIMINARY VERIFICATION OF THE TOOLS: COGNITIVE REFLECTION TEST (CRT) AND BASE-RATE TASKS TEST (BRT)[1]

Abstract

The article presents the preliminary verification of two instruments measuring the analytical style of information processing: Cognitive Reflection Test (CRT) by Frederick and Base-Rate Tasks (BRT) test by Kahneman and Tversky. The tests' reliability was analysed, and their validity was preliminarily verified by looking for correlations of their results with the results of other instruments measuring individual characteristics of cognitive functioning, as well as differences between sexes and differences related to university faculties. The participants were 374 students, including 174 males and 200 females representing different faculties. The obtained results confirmed the instruments' reliability (CRT: Cronbach's α = .74; BRT: Cronbach's α = .80). The results' correlation with the results of another instrument measuring the analytical style – the Intuitiveness–Rationality (IR) questionnaire – was weak. The obtained data were similar to those found in the research by Pennycook, Cheyne, Seli, Koehler, and Fugelsang (2012), which proves the correct adaptation of the tests. Based on the conducted analysis, differences between sexes were shown (stronger analytical style was found in males), as well as differences connected with the choice of a university course (stronger analytical style was found in students of technical sciences and psychology).

Keywords: individual differences, dual-process theories, cognitive styles, analytic style, intuition

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1. Introduction

In the last two decades, a lot of research in the field of cognitive psychology has been devoted to two ways of solving problems and making decisions related to two different information processing systems (Evans, 2008, 2010; Evans & Stanovich, 2013; Kahneman, 2003; Stanovich, 2009, 2011). These systems are an intuitive system (System 1) and an analytical system (System 2; Evans, 2010). Differences in the word tags used for them reflect different specific characteristics given by different authors. And so, apart from the terms *intuitive* and *analytic* (Hammond, 1996), the following terms are used: *implicit* and *explicit* (Reber, 1993), *experiential* and *rational* (Epstein, Pacini, es-Raj, & Heier, 1996), *heuristic* and *systematic* (Chaiken, 1980), *heuristic* and *analytic* (Evans, 2006), *associative* and *rule-based* (Sloman, 1996); *reflexive* and *reflective* (Lieberman, 2003), *intuitive* and *rational* (Kolańczyk, 1999; Kolańczyk & Świerzyński, 1995).

Processes of type 1 are evolutionarily older and characterized by automaticity (they become activated as soon as stimulation appears), with speed, low amount of the energy needed, and thus: little effort needed to process information, relation with unconsciousness and contextual thinking, and a direct link to emotions and implicit memory. They are characterised by little information processing capacity but do not require a lot of energy. They do not allow new problems as well as those requiring a high degree of accuracy to be solved. Due to their speed, they are not very sensitive to disturbances caused by current thoughts and actions, require little concentration and are not perceived by a person as unpleasant.

Type 2 processes are: relatively slow, awareness and reflection-related, which requires a lot of energy to process information, controlled, linked to explicit memory, based on abstract thinking and not directly linked to emotions. They enable a wide range of new and original problems to be solved and decisions to be taken, ensuring high accuracy of solutions. However, they involve considerable energy costs, which means that they are slower to act, tend to be easily disrupted by other thoughts and actions, and require a high level of concentration, which a person often perceives as unpleasant.

Both systems affect each other and in the light of the theory of two systems, a compromise is reached between them; this is the energy compromise that a person makes to solve a problem in a way that is right for him or her. If a person devotes more energy, he or she will be guided more by analytical thinking (Toplak, West, & Stanovich, 2014).

The development of the theory of two systems has contributed to the development of research in the field of differential psychology, especially concerning cognitive styles. The tendency to use System 2, which is subject to clear individual differentiation, is described as an analytical style. Numerous studies indicate that individual differences concerning the involvement in Type 2 processes are revealed in the course of reasoning and decision-making tasks, regardless of cognitive abilities (e.g., De Neys & Glumicic, 2007; Stanovich & West, 1998, 2000; Toplak, West, & Stanovich, 2011, 2014). Several studies have been carried out so far, which have found, among other things, positive relations, e.g., between analytical style and openness to experience (Browne, Pennycook, Goodwin, & McHenry, 2014), analytical style and creativity (Barr, Pennycook, Stolz, & Fugelsang, 2014). A negative correlation of the analytical style has been demonstrated, for example, with moral values (Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014a; Rozyman, Landy, & Goodwin, 2014), moral judgments (Paxton, Ungar, & Greene, 2012; Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014a), as well

as with religiousness (Gervais & Norenzayan, 2012; Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014b; Pennycook, Cheyne, Koehler, & Fugelsang, 2013; Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012; Shenhav, Rand, & Greene, 2012; Pennycook, Cheyne, Koehler, & Fugelsang, 2013).

The research presented here aimed to test the usefulness of two types of tasks for measuring the analytical style of information processing: tasks adapted to the Polish population from the Cognitive Reflection Test (CRT; Frederick, 2005) and tasks used by Kahneman and Tversky in Base-Rate Tasks decision-making research (BRT; Kahneman & Tversky, 1973; De Neys & Glumicicic, 2007). Firstly, the reliability of the tests was assessed. Secondly, their validity was preliminarily verified by looking for correlations of their results with the results of other instruments measuring individual characteristics of cognitive functioning, as well as differences between sexes and differences related to the faculty.

2. Method

2.1 Participants and Procedure

The participants of the study were 374 students (age: $M = 21.7$ years, $SD = 1.9$), including 174 males and 200 females. The study participants were full-time students and represented the following areas of study: technical (students from a Technical University and Fire Service School, both active service and civilian students), social (students of pedagogy, psychology and journalism) and physical culture (students from the University of Physical Education).

The participants filled in a battery consisting of the tools described below and a fiche (sex, age and type of university). The tools were arranged in the following order: CRT test, IR questionnaire, Kahneman and Tversky (BRT) task set. The study was carried out in groups.

2.2 Tasks

Cognitive Reflection Test (CRT). The *Cognitive Reflection Test* (CRT; Frederick, 2005; Gervais & Norenzayan, 2012; Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012; Shenhav, Rand, & Greene, 2012) contains three quasi-mathematical problems that give the subjects a hidden desire to deal with them quickly and thoughtlessly, but which does not lead to a correct solution. For the correct answer, the examined person receives one point. A sample task is as follows:

"A baseball bat and a ball cost together PLN 11. The baseball bat costs PLN 10 more than the ball. How much does the ball cost? _____"

In this task, the answer *PLN 1* comes to mind intuitively, but it is not correct. According to the test assumptions, the Type 1 process caused the choice of intuitive response. To solve the problem correctly, the Type 2 process needs to be activated - it enables going beyond the intuitive thought and starting mathematical operations aimed at a correct solution (PLN 0.50). This marks the analytical style.

Kahneman and Tversky's (BRT) Tasks. The study used a set of problems from the area of Kahneman and Tversky's decision-making (BRT; 1973; De Neys, & Glumicicic,

2007), which lead to a conflict between an "ingrained" stereotype about e.g., sex or profession and information about objective probability. Here's an example:

In a study 1000 people were tested. Among the participants there were four men and 996 women. Jo is a randomly chosen participant of this study.

Jo is 23 years old and is finishing a degree in engineering. On Friday nights, Jo likes to go out cruising with friends while listening to loud music and drinking beer.

What is most likely?

a. Jo is a man

b. Jo is a woman

A good answer to the above task requires the use of logic and probabilistic thinking. However, the task has been constructed in such a way as to evoke intuitive thinking, which, as more heuristic, conflicts with the principles of probability. Type 1 Processes are automatic and fast, so the first look at the problem imposes an intuitive answer (Jo is a man), i.e. stereotypical. Type 2 Processes require more energy and involve consideration of a greater amount of data the task provides. In this case, it is necessary to pay attention to the number of people of a given sex, and thus to move towards probability thinking and to go beyond the stereotype (Jo is a woman). The principles of logic and probability characterise the analytical style.

In addition to the tasks where, as in the example above, there is a conflict between stereotype and logic (IBRT – Incongruent Base-Rate Tasks), the set includes two other types of problems: those where the stereotypical response is identical to the probability response (CBRT – Congruent Base-Rate Tasks), and those where no stereotype occurs (NBRT – Neutral Base-Rate Tasks).

An example of CBRT is the following task:

In a study 1000 people were tested. Among the participants there were 995 who buy their clothes at high-end retailers and five who buy their clothes at Wal-Mart. Karen is a randomly chosen participant of this study.

Karen is a 33-year-old female. She works in a business office and drives a Porsche. She lives in a fancy penthouse with her boyfriend.

What is most likely?

a. Karen buys her clothes at high end retailers

b. Karen buys her clothes at Wal-Mart

"In a study 1000 people were tested. Among the participants there were five who campaigned for George W. Bush and 995 who campaigned for John Kerry. Jim is a randomly chosen participant of this study.

Jim is 5 ft and 8 in. tall, has black hair, and is the father of two young girls. He drives a yellow van that is completely covered with posters.

What is most likely?

a. Jim campaigned for George W. Bush

b. Jim campaigned for John Kerry"

The applied set consists of 18 tasks (six of each type, arranged randomly). An indicator of the analytical style is the resistance to the stereotype and use of logic and probability thinking in IBRT problems (the more correct answers, the greater the intensity of this style). NBRT problems, on the other hand, can be considered as a measure of cognitive capacity; solving them correctly requires the use of the principles of logic and probability in a situation that is free from the distorting influence of intuitive think-

ing. If the examined person is unable to solve such tasks, then his/her cognitive style should not be evaluated (e.g., Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012). Therefore, NBRT tasks can be treated as a kind of control scale. The CBRT tasks are buffer tasks.

Questionnaire Intuitiveness–Rationality (IR). The Intuitiveness–Rationality Questionnaire (IR; Kolańczyk & Świerzyński, 1995) is a tool for assessing the preferred way of thinking: intuitive vs. rational The IR questionnaire is a reliable and accurate tool for measuring the intuitive style, therefore it was used to assess the accuracy of the CRT test and the Kahneman and Tversky task set.

An example of a questionnaire item is as follows:

"I get to know someone much better when I do not know anything about him or her before and I just sense him or her myself."

The task of the examined person is to respond to the statement and choose answers on a scale from 1 to 4, where 1 means *definitely yes*, and 4 means *definitely not.* The overall result, which is an indicator of rational style, includes all items. Part of the positions has inverted scoring. The higher the questionnaire score, the more intuitive the examined person is.

3. Results

3.1 Cognitive Reflection Test (CRT)

The test turned out to be difficult for the respondents: the average score was 1.17 (with a possible maximum of 3.0), the difficulty rate was 40% (the ratio of the number of points obtained by all the respondents to the number of points possible to obtain). The analysis of the frequency of good solutions showed that over 40% of the respondents did not give a single correct answer, while all tasks were solved correctly by just over 20%. For CRT the α-Cronbach coefficient was calculated, this was 0.74.

Due to the data found so far in the literature indicating sex differences in cognitive styles, the CRT results of men and women were compared, expecting the former to be higher. Due to the nature of the distributions received, two categories were created: 0 points (all three incorrect answers) and 1-3 points (at least one correct answer). Table1 compares the frequency of these response categories in men and women.

Table 1
Percentage of correct response in CRT for women and men

No. cor. resp.	Women $N = 200$		Men $N = 174$	
	Frequency	%	Frequency	%
0	109	72.3	45	45.8
1–2–3	91	27.7	129	54.2

Note. No. cor. resp. = number of correct answers; % = percentage of correct answers.

Table 1 shows that men more often gave correct answers than women. This difference was found to be significant $\chi^2(df = 1) = 31.50, p < .001$. The ϕ coefficient calculated from Table 1 was: $\phi = 0.29, p < .01$, which indicates a moderate strength of the relation between the analysed variables as well as the fact that men use an analytical style of thinking more often than women. Frederick (2005) also reported the existence of important and significant sex

differences (the difference in the correct responses, as in this study, was over 50 per cent in favour of men). Replicating studies were conducted by Toplak, West, & Stanovich (2014) and confirmed that men more often gave correct answers.

Many existing data also indicate a link between cognitive style and personal interests. Such a relation has been found, for example, regarding field dependence-independence (Matczak, 2007), which is clearly related to the globality-analyticity dimension (cf. e.g., Nosal, 1990). More analytical style can be expected from those with interests in science and less intense from those with humanistic and social interests. The next analysis, therefore, compares the results in CRT of students of seven different faculties. The results are presented in Table 2.

Table 2
Percentage of correct answers in CRT versus field of study

	AWF		Pol		Psych		Jo		Ped		FFs		FFc	
n	69		37		40		51		52		95		30	
Nga	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
0	45	82.1	13	62.3	7	40.0	27	66.7	42	92.3	11	31.6	9	56.7
1–2–3	24	17.9	24	38.7	33	60.0	24	33.3	10	7.7	84	68.4	21	43.3

Note. Nga = number of good answers; Freq. = frequency; % = percentage of correct answers; AWF = University of Physical Education; Pol = Technical University; Psych = psychology; Jo = journalism; Ped = pedagogy; FFs = fire fighting (firefighters); FFc = fire fighting (civilians).

It turned out that students of fire fighting (firefighters and civilians) and psychology have the highest frequency of good answers, which means that they are more analytical. The lowest percentage of correctness was found in the case of students of pedagogy and at the University of Physical Education. These differences were found to be significant: $\chi^2(df = 6) = 98.75$, $p < .001$. The strength of the relation between the analysed variables measured by Cramer's **V** statistics is average, **V** = .51, and indicates that there is a clear link between the analytical style and the faculty. Students of technical sciences and psychology are guided by a more analytical style of thinking. Therefore, the second part of the conclusion that a greater increase in analytical style can be expected from those with interests in science and less from those with humanist and social interests is in a clear contradiction with the expectations drawn from previous studies mainly on the field dependence-independence. Perhaps this should be explained by the differences between the two dimensions. Although there is a similarity between them, one can also point out an important difference – field dependence-independence mainly describes individual differences in perception, the analytical character measured by CRT determines the features of thinking. In the next analysis, a relation between the CRT test and the IR questionnaire was expected, which is a tool constructed to measure the dimension of cognitive style intuitive-rationality for Polish groups and is characterized by high reliability and accuracy. Demonstrating such a link would be in favour of the relevance of the CRT, so for its examination, the results were correlated with those of the IR questionnaire. The Pearson coefficient *r* turned out to be insignificant and was .05, which is contrary to expectations.

3.2 Kahneman and Tversky's (BRT) Tasks

Neutral tasks (NBRT). As has already been said, NBRT problems are treated as a measure of cognitive ability, so the inability to solve them would be grounds for not taking a person's results into account when analysing cognitive style. However, there was no one in the study group who would not solve at least one task correctly, 70% of the respondents gave correct answers in four to six tasks. On this basis, it was decided not to eliminate any person from further analysis. The results of groups differing in sex were then compared. These are presented in Table 3.

Table 3
Percentage of relevant responses in CRT for women and men

	Women $N = 200$		Men $N = 174$	
Nga	Frequency	%	Frequency	%
1–3	67	33.5	44	25.3
4	45	22.5	37	21.3
5–6	88	44.0	93	53.5

Note. Nga = number of correct answers; % = percentage of correct answers.

Based on the above results, it turned out that women and men do not differ in their cognitive abilities $\chi^2(df = 2) = 3.89$, $p < .05$. This result is consistent with the literature. Small differences were found when comparing the results of people studying different faculties, as shown in Table 4.

Table 4
Percentage distribution of correct answers in NBRT in individual university faculties

	AWF		Pol		Psych		Jo		Ped		FFs		FFc	
n	69		37		40		51		52		95		30	
Nga	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
1–3	23	33.3	11	29.7	5	12.5	19	37.3	23	44.2	20	21.1	10	33.3
4	21	30.4	3	8.2	5	12.5	11	21.6	13	25.0	23	24.2	6	20.0
5–6	25	36.3	23	62.1	30	75.0	21	41.1	16	30.8	52	54.7	14	46.7

Note. Nga = number of correct answers; Freq. = frequency; % = percentage of correct answers; AWF = University of Physical Education; Pol = Technical University; Psych = psychology; Jo = journalism; Ped = pedagogy; FFs = fire fighting (firefighters); FFc = fire fighting (civilians).

The most correct answers were given by students of psychology and Technical University, followed by fire fighting students $\chi^2(df = 12) = 33.23$, $p < .01$. The strength of the relation between the analysed variables measured by Cramer's V statistics is V = .22, $p < .01$ and indicates a weak relation between cognitive ability and the faculty.

Tasks with stereotypes (IBRT). As we remember, the IBRT is the right part of the test to measure cognitive style. To estimate the reliability of the test, the Cronbach coefficient α for IBRT was used, which is .80, and indicates high internal compliance. Analyses of gender differences were also conducted. The results are presented in Table 5.

Table 5
Percentage of correct responses in CRT for women and men

	Women $N = 200$		Men $N = 174$	
Nga	Frequency	%	Frequency	%
0	89	76.3	48	66.6
1–6	111	23.7	126	33.4

Note. Nga = number of correct answers; % = percentage of correct answers.

It turned out that men reveal analytical style slightly more often than women – $\chi^2(df = 1) = 11.46$, $p < .01$. However, the strength of the relationship between the analysed variables (sex and percentage of relevant responses) measured by the ϕ coefficient is weak and amounts to $\phi = 0.17$, $p < .05$. Further analyses compared the correctness of answers given by students of different faculties.

Table 6
Percentage of correct answers in IBRT vs. the field of study

	AWF		Pol		Psych		Jo		Ped		FFs		FFc	
n	69		37		40		51		52		95		30	
Nga	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
0	26	81.7	8	59.9	11	52.9	23	79.1	31	96.9	28	67.6	10	68.9
1–6	43	19.3	29	40.1	29	47.1	28	20.9	21	13.1	67	32.4	20	13.1

Note. Nga = number of good answers; Freq. = frequency; % = percentage of correct answers; AWF = University of Physical Education; Pol = Technical University; Psych = psychology; Jo = journalism; Ped = pedagogy; FFs = fire fighting (firefighters); FFc = fire fighting (civilians).

It turned out that the field of study significantly differentiates the students results $\chi^2(df = 6) = 20.70$, $p < .01$. The strength of the relation measured by the Cramer's V coefficient indicates the existence of a clear relation and dependence between the analytical style and the faculty in IBRT (V = .23, $p < .01$). Students of psychology, Technical University and fire fighting gave the most analytical answers. Thus, mainly students of technical sciences and psychology demonstrate the analytical style. As in previous analyses regarding CRT, the relatively high performance of psychology students is not in line with expectations.

As mentioned earlier, the use of an IR questionnaire in the research was intended to check the relevance of the IBRT task set. Average IR correlations were expected, which would be a strong argument for IBRT accuracy. It turned out that, as expected, IBRT and IR results correlated positively with each other, but the strength of the relation is very low – the Pearson coefficient r was only .12. A moderate correlation of IBRT with NBRT, at .49, may indicate a certain saturation of tasks that measure the analytical style

of cognitive skills. In the Pennycook, Cheyne, Selie, Koehler, and Fugelsang studies (2012), the strength of the relation was slightly less, with the Pearson coefficient *r* of .32.

3.3 Cognitive Reflection Test (CRT) and Kahneman and Tversky's Tasks

Recent analyses are intended to demonstrate a relation between CRT and IBRT, which would indicate the similarity of the constructs examined (these are the tools to measure the analytical style), but no relation between CRT and NBRT is expected. Such a relation may suggest that the tests used can measure separate constructs, so at the end of the analyses, correlation coefficient of IBRT and NBRT to CRT was calculated. After the analysis, it turned out that there is a positive (albeit low) relation between the tasks and the stereotype – IBRT (.23) and neutral tasks – NBRT (.21) with CRT. In the Pennycook, Cheyne, Selie, Koehler, & Fugelsang (2012) research, the relation between CRT and IBRT was .26, and between CRT and NBRT .26.

4. Discussion

The research presented here aimed to check the usefulness of the CRT test (Cognitive Reflection Test) and Kahneman and Tversky's tasks to measure the analytical style in Polish groups. Both tests differentiate between the respondents and are highly reliable. The research carried out allows to observe gender differences in the framework of analytical style (in favour of men), replicating studies carried out by Frederick (2005) and Toplak, West, and Stanovich (2014). Such differences were also found between students of different faculties (analytical style in technical sciences and psychology students). However, the NBRT tasks, which control cognitive capacity, no sex differences have been found, which is in line with their purpose – to measure cognitive capacity that is not gender-specific.

A link between the IBRT and CRT tests and the IR questionnaire was expected; in the case of the former, such a link exists but is weak, whereas in the case of CRT, no link has been demonstrated, which can be explained by different nature of the tools: Kahneman and Tversky's and CRT tasks are test tools, IR is a questionnaire.

A link between CRT and IBRT tests was demonstrated, but also between CRT and NBRT tests. Demonstrating the latter relation is problematic in that it may support the claim that the CRT test measures not so much the analytical style but the cognitive skills, as well as the IBRT tasks, or that the tools measure separate constructs, although this relation is similar to that in the research of Pennycook, Cheyne, Selie, Koehler, and Fugelsang (2012), which speaks in favour of the correctness of the test adaptations. There may be different aspects of the analytical style of information processing that are culturally diverse.

In the future, it is advisable to carry out further research on the accuracy of the Polish adaptation of the CRT test and Kahneman and Tversky's tasks, with a broader range of age groups and the use of other tools to assess accuracy. It is also worth examining the relationship between cognitive style and personal interests.

The appearance of a newer version of the CRT test, extended by four additional tasks, may contribute to further development of research on analytical style in Polish groups. However, it seems that the two tools discussed here can already be used today for further scientific research on the analytical style of information processing.

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