

# Collective Development of Cognitive Abilities Using the "4C" Approach

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**Abstract**— The article continues a series of papers on collaborative research and learning. The subject of the study is a system consisting of an educational project group, subjects prescribed and a cognitive learning infrastructure. The latter includes the hardware and software components, an infrastructure service team, and a mentor component. The basic concept of the study is the necessity for mutual adjustment of all components of this system. The main research tool is the "4C" approach, which was the result of the development of cross-technologies of the situational center. The approach is based on the "collaborative", "cognitive", "configurable", and "convergent" concepts. The service team consisted of a logician, a computer assistant and a facilitator. The members of the study groups were diagnosed using various methods, including MBTI. The possibilities of the approach are illustrated by two experimental studies of the authors. The first study involved the implementation of a reflexive version of the well-known Rock-Paper-Scissors game. The peculiarity was that the decision on the choice was made by pairs of players. The task of the study was a preliminary analysis of the algorithms for the solution, which were formed in groups. The second study consisted of an experimental study of the "uncanny valley" phenomenon. The peculiarity of this study was to test the hypothesis about the possibility of explaining this phenomenon using the theory of catastrophes in Whitney assembly format. The experiments were carried out with the participation of schoolchildren and students of Omsk and Vladivostok.

**Keywords:** *intelligence, reflection, abilities, collective, non-transitivity, robots, uncanny valley, catastrophe theory.*

## I. INTRODUCTION

The article continues a series of academic papers by the authors devoted to collaborative research and teaching [1], [2], [3]. The subject of the study is a system consisting of an educational project group, subjects prescribed and a cognitive learning infrastructure. The latter includes the hardware and software components, an infrastructure service team, and a mentor component. The basic concept of the study is the necessity for mutual adjustment of all components of this system. This requires the analysis of many processes and their interactions. The research is multidisciplinary, and therefore the team of authors includes specialists in the field of mathematics, psychology, education and computer sciences. The long-term cooperation of the authors of this publication has allowed them to form an approach to the implementation of multidisciplinary research, so-called "4C". The authors consider the application of this approach to be quite

productive. The purpose of this article is to present a variant of a systematic framework for educational research, as well as to indicate the various approaches, the combined use of which can provide significant synergistic effects.

## II. METHODOLOGY AND THE PROBLEM STATEMENT

The main research tool is the "4C" approach, which was the result of the development of the authors' cross-technologies in the situational center. The approach is based on the "collaborative", "cognitive", "configurable", and "convergent" concepts. That's why it was called the "4C" approach. The service team consists of a logician, a computer assistant and a facilitator. Study group members were diagnosed using various techniques, including the well-known Myers-Briggs Type Indicator (MBTI), Kelly's constructs [4] and others [5], [6]. Reflexive models [7], [8], as well as the concepts of mathematical substantiation of hypotheses [9], collective expertise [10] and "antifragility" [11] are important tools.

The possibilities of the approach are illustrated by two experimental studies by the authors, described below. These experiments were carried out by the authors in 2021 with the participation of schoolchildren and students of Omsk and Vladivostok.

## III. REFLECTIVE VERSION OF THE GAME "ROCK-PAPER-SCISSORS"

The game "Rock-Paper-Scissors" has been known for a long time. Championships with a large prize fund are held on it. There is a 5-man team game version, where the choice of the team is determined by a majority. This game is of great interest from the perspective of studying a person's reaction to situations with non-transitive preferences [12].

The peculiarity of our variant was that the decision on the choice was made by teams of two players. This meant that instead of instantaneous reflection at the subconscious level, rational logical reflection was included. Also, each pair had to choose any two of the three possible options for one move. Technically, this meant choosing two options out of three substitute items. These substitutes were office supplies: paper clip instead of stone, pushbutton instead of scissors, and rubber band for banknotes instead of paper.

The selected items were placed in an opaque jar, which the assistants have been passing to the opposing team, which meant the move was made. At the same time, the team gets the jar with items selected by the opposing team. The teams

kept logs in parallel, which, in addition to collecting statistics, made it possible to correct errors.

The task of our study was not to find a winning strategy, but to preliminary analyze the decision algorithms that were formed in groups. This analysis is currently not completed, but it can be noted that many times there was a seizure of leadership in a pair. Thus, the game was reduced to the usual version of the instantaneous reflection.

#### IV. THE PHENOMENON OF THE "UNCANNY VALLEY"

The second research consisted of an experimental study of the phenomenon of the "uncanny valley" [13]. This phenomenon has attracted the attention of many researchers from various disciplines, both the humanities and natural science subjects [14], [15], [16], [17].

The peculiarity of our study was to test the hypothesis that it is possible to explain this phenomenon using the theory of catastrophes by analogy with the explanation of the phenomenon of bistability of visual perception and hysteresis [18].

We can explain the phenomenon of hysteresis by the example of reading a sequence of words spelt out in the Latin alphabet. It is assumed that reading is carried out by a person who knows English and Russian. In this sequence, reading and interpretation of the word "*cop*" in the middle of the line depends on whether these words are read from left to right or from right to left. In the first case, the word is interpreted as "*policeman*", in the second one it is interpreted as "*trash*". The sequence is shown below.

*list, word, stone, gun, cop, cepa, poca, xop, oca.*

The formation of this hypothesis is due to two reasons. Firstly, the presence in the experimental results of configurations such as "valley", "cliff", "beak", and so on is common to the projections of catastrophe theory. Secondly, resemblance to a person can hardly be considered a sufficient basis for sympathy. People can be ugly and dangerous. On the contrary, a person may feel sympathetic towards various objects that are much different from people. In this regard, a search was carried out for an additional scale to assess the characteristics of objects.

In addition to the final antipathy-sympathy (AS) scale, two basic scales were formed: difference-similarity (DS) and threat-safety (TS). Each scale contained 5 gradations. The gradations were set as integers in the range from -2 to +2. Higher values corresponded to a higher level in each scale: the sympathy AS (likeability of the stimuli), the human likeness DS (anthropomorphism) and safety TS.

It is necessary to note some important features. The original text [13] does not describe the methodology and the groups who took part in the study. Some publications indicated that this was only a hypothesis, others mentioned a survey. However, all these go back to the Japanese culture and traditions. The publication [14], which is related to our study, reveals that all participants in the experiment were associated with a University in the Kyoto district of Japan. Participants were paid a fee.

Our cohort is Russian-speaking young people from Siberia and the Far East. Obviously, cultural differences are a significant factor. Even more significant is the fact that the original study was carried out more than half a century ago

(the first Japanese-language publication dates to 1970). During this time, the topic of robots, artificial intelligence, zombies, vampires, and so on became one of the leading subjects in the mass media. We should mention the training "Zombie Apocalypse" in the USA (CONPLAN 8888 also known as Counter-Zombie Dominance, 2011). In addition, we note that the tradition of celebrating Halloween appeared in Japan not long ago. Now various kinds of artifacts that were previously associated with the concept of "terrible" or "uncanny" are being actively promoted in the mass media. An interesting study of this concept was done in [18].

In one of our pilot studies, senior students were asked to choose their classmate from famous characters. In addition to the relatively predictable Winnie-the-Pooh, Shaun the Sheep and Mason "Dipper" Pines, the god of death Ryuk and the one-eyed monster Mike Wazowski were also named. In our other pilot study, which evaluated famous people and robots, the robot vacuum cleaner received the highest rating on the "liking-disliking" AS scale. The greatest Russian poet A.S. Pushkin was rated quite high, but one of the participants gave him the minimum mark. To justify an assessment, it was indicated that children at school had to memorize his poetry.

In our study, 25 photographs of real-life robots, toys, and movie characters were selected for the experiment. A photograph of a man wearing the popular Guy Fawkes mask was also used. The photographs were selected in such a way that the organizers of the experiment could classify them according to the DS and TS scales described above, as well as place photographs one by one in each position of the experiment matrix (Table 1). To make changes during the experiment, the coordinates of the matrix cells were taken similar to the coordinates of a checkerboard, and the values corresponding to the scales were used as additions to the coordinates. Each photo initially corresponds to a certain cell of the matrix. During the experiment, each photo can be replaced with a photo with the same values on both scales. In Table 1, some cells are filled with the names of well-known characters.

TABLE I. EXPERIMENT MATRIX

TS	№	DS				
		-2	-1	0	+1	+2
		A	B	C	D	E
+2	1	vacuum cleaner -robot	Johnny 5			David AI
+1	2	WALL-E	Cook robot			Sofia robot
0	3	Dog a toy robot				Mask of Guy Fawkes
-1	4					
-2	5	Snake a toy		Zombie a toy		

The participants of the experiment were schoolchildren and students of Omsk and Vladivostok. There were 5 groups of different sizes. The total number of participants was 50. The age of the participants in the experiment ranged from 17 to 30 years. By contrast with the experiment in Japan [14], we did not pay for participation in the experiment. Our resource was the interest of the participants in the research topic. We also did not have an opportunity to use a lot of

computers, so the participants could see these photographs on a big screen. The marks were recorded by the participants on specific paper forms. The survey was anonymous.

In the course of the experiment, all 25 photographs in a certain sequence were presented to the participants to assess them using the final AS (antipathy-sympathy) scale. To test the hypothesis of a catastrophe such as Whitney assembly it was necessary to use two ways of bypassing the bifurcation point. In our designations, this corresponded to the presentation of photographs in the direction from E1 to A1 and further along the DS scale (Test-25-L), and in the other direction it was done from E1 to E5 and further along the TS scale (Test-25-R). The meaning of these bypasses was specified in this way. Left bypass: first, the degree of similarity to a person decreases, and then the threat increases. Right bypass: first, the threat increases, then the degree of similarity to a person decreases. The mean values of estimates are presented in Table 2 and Table 3.

TABLE II. ESTIMATES OF THE LEFT BYPASS

	A	B	C	D	E
1	0,56	0,44	0,08	0,66	0,43
2	1,22	0,21	0,19	-0,25	-0,28
3	0,93	-0,49	1,04	-0,23	-0,83
4	0,63	-1,12	-0,63	-1,34	0,15
5	-0,13	-0,30	-0,44	-1,21	-0,32

TABLE III. ESTIMATES OF THE RIGHT BYPASS

	A	B	C	D	E
1	1,08	-0,39	-0,47	0,08	-1,00
2	0,55	-0,07	0,22	-0,21	-1,23
3	0,46	-0,46	0,23	-0,91	-1,07
4	-0,40	-1,30	-1,16	-1,53	-0,07
5	-0,68	-0,92	-1,22	-1,22	-0,83

The main results are presented in Table 4. There is a sufficient correlation between the assessments of different groups. Predictably, the average value of the ratings drops sharply at right bypass. This can also be seen in the increase in negative ratings for the entire set of 25 slides.

We can add that the highest marks were given to the characters known from movies, such as WALL-E, Johnny 5 and David from the movie "AI".

TABLE IV. FINAL VALUES

Bypass	correlation coefficient	general average	negatively rated slides
Left	0,80	0,01	13
Right	0,71	-0,50	19

In general, the results of the experiment showed that the hypothesis of representing the assessment process using a catastrophe such as Whitney assembly can be accepted as the working one. Accordingly, the "uncanny valley" or "cliff" is the projection of a fragment of the response surface in the neighborhood of the bifurcation point. Figure 1 shows a way of designating this projection using emoticons corresponding to negative ratings.

	A	B	C	D	E
1	0,56	0,44	0,08	0,66	0,43
2	1,22	0,21	0,19	☹	☹
3	0,93	☹	1,04	☹	☹
4	0,63	☹	☹	☹	☹
5	☹	☹	☹	☹	☹

Fig. 1. Projection of the response surface

It is possible to modify the scales used, which will make it possible to bring the response surface to the canonical form of the Whitney assembly. However, for our purposes, it is sufficient to state the situation of abrupt changes in estimates depending on the organization of the sequence of stimulus presentation.

Our research continues. The "4C" approach requires the following work.

- It is necessary to create a methodology for **collaborative** assessment, including assessment by artificial intelligence systems, as well as interactive assessment in remote interaction using such tools as Google Sheets.

- We should create a **configurator** as a language for representing a situation under consideration. This configurator can include fundamental reflexive models of the psyche [7], [8].

- We should use additional **cognitive** assessment tools (neurointerfaces, eye-trackers, etc.), as well as present the results using cognitive graphics [20]. It should be noted that according to the authors' approach, the examination samples should not be presented sequentially, but all at the same time, in the form of a panorama.

- We should ensure **convergence** of the assessment processes by identifying the tasks for which such assessment is useful. Some of these tasks are listed below.

It is of interest to study the interaction of groups of people and robots. An example is the problem of modeling a group of two conflicting children, each of whom is accompanied by a robot nanny [21]. Solving such problems requires teaching robots to assess the hazard and potential of various situations. It is worth mentioning that in 2003 the Doki robot could identify the age, gender and ethnicity of a human by his/her face [22]. Doki was registered in the Guinness Book of World Records as "the World's Most Gender-Aware Robot".

It is appropriate here to quote the theses of the discoverer of the phenomenon, which have not lost their relevance [13]: «*We should begin to build an accurate map of the uncanny valley so that through robotics research we can begin to understand what makes us human. This map is also necessary to create— using nonhuman designs— devices to which people can relate comfortably.... I predict that it is possible to create a safe level of affinity by deliberately pursuing a nonhuman design.*».

## V. CONCLUSION

A version of the system framework based on the "4C" approach for research in the field of education focused on collective processes is presented. The descriptions of two examples of experimental studies are given, which make it possible to reproduce the components of the proposed approach when solving various research problems. Research topics on the direction of interaction between groups of people and robots are proposed.

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