The research on anticipation of vessel captains by the space of Kelly's graph

Enfoques de identificación de anticipación de capitanes en el espacio del grafo de Cayley

Ph. D. Pavlo Nosov
Kherson State Maritime Academy, Ukraine
ORCID iD: https://orcid.org/0000-0002-5067-9766 ;
Scopus Author ID: 57211927353; ResearcherID: G-1196-2019
Doctor of Psychological Sciences Ihor Popovych
Kherson State University, Ukraine
ORCID iD: https://orcid.org/0000-0002-1663-111X ;
Scopus Author ID: 57208214862; ResearcherID: F-3030-2019
Ph. D. Serhii Zinchenko
Kherson State Maritime Academy, Ukraine
ORCID iD: https://orcid.org/0000-0001-5012-5029 ;
ResearcherID: G-7831-2019
Doctor of Pedagogical Sciences Vasyl Cherniavskyi
Kherson State Maritime Academy, Ukraine
ORCID iD: https://orcid.org/0000-0001-7551-4186 ;
ResearcherID: AAC-8366-2020
Doctor of Psychological Sciences Viktor Plokhikh
South Ukrainian National Pedagogical University named after K. D. Ushynsky, Ukraine
ORCID iD: https://orcid.org/0000-0001-7897-3417 ;
ResearcherID: I-3897-2018
Senior Lecturer Halyna Nosova
Kherson Polytechnic Professional College
of Odessa National Polytechnic University, Ukraine
ORCID iD: https://orcid.org/0000-0003-1273-5656 ;
ResearcherID: AAL-3264-2020

Abstract

The paper examines the issue of identifying *anticipation* of ship captains in critical situations. The purpose of the study is to develop a fundamentally new formal approach to create a map of captains' negative *anticipation* in order to prevent disastrous consequences on maritime transport caused by a *human factor*. To achieve the purpose of the study the following steps were taken: we examined the principles of the systemic approach conforming to the concept of the methodology of an individual's expectations and the levels of formalization; determined the components of an elementary formal and mathematical system within the framework of the approach under study; formulated the order of structural principles of creating the model of an individual's *anticipation* in the form of axioms. The experiment using the maritime navigation simulator Transas navigation simulator NTPRO 5000 made it possible to present a captain's behavior as Kelly's graph allowing us to identify the points of manifestation of his

anticipation. The research also determined the correlation of these points and changes in technical parameters of the trajectory of a ship route confirming the research hypothesis.

Resumen

El artículo está dedicado al problema de identificación de la *anticipación* del capitán del barco en situaciones críticas. El propósito del artículo es desarrollar un enfoque formal fundamentalmente nuevo para la formación de un mapa de *anticipación* negativa de los capitanes para evitar consecuencias catastróficas en el transporte marítimo debido al *factor humano*. Para lograr este objetivo, se hizo lo siguiente: se consideraron los principios del enfoque sistémico, acordes con la metodología de expectativas sociales del individuo y los niveles de formalización; se determinaron los componentes de un sistema elemental formal y matemático; se formó el orden de los principios estructurales de la formación del modelo de *anticipación* de la personalidad en forma de axiomas. El experimento realizado con el uso del simulador de navegación marítima Transas navigation simulator NTPRO 5000 permitió representar el comportamiento del capitán en el grafo de Cayley e identificar los puntos de manifestación de su *anticipación*. Fue determinada la correlación de estos puntos con respecto a cambios en los parámetros técnicos de la trayectoria del barco, confirmando la hipótesis del estudio.

Key words

Anticipation – Expectations – *Human Factor*

Palabras clave

Anticipación – Expectativas – *Factor humano*

Introduction

In the methodology of an individual's *anticipation* and expectations there are quite stable structures making it possible to determine basic significant identifiers of the research object as a mental process, mental state[1] and the totality of properties of this phenomenon with a high degree of reliability[2]. One of such identifiers is the ability to anticipate the future, self-regulating activity of and

[1] A. Tyshkovsky, "Research on Expectations of High Educational Establishment's Graduates According Entrepreneurial Activity". In: Proceedings of '98 International Conference on Management Science y Engineering (p. 871). (Harbin, H: Institute of Technology Press. 1998).

[2] Yu. V. Cheban; O. Ya. Chebykin; V. V. Plokhikh y A. V. Massanov, "Emotional factor of competitive self-mobilization of professional rowers". Insight: the psychological dimensions of society, num 3 (2020): 28-43; I. S. Popovych, "Motivational component of socio-psychological expectations". Problems of general and pedagogical psychology, Vol: XIII num 4 (2011): 290-297 y R. Shevchenko; I. Popovych; L. Spytska; P. Nosov; S. Zinchenko; V. Mateichuk y O. Blynova, "Comparative analysis of emotional personality traits of the students of maritime science majors caused by long-term staying at sea". Revista Inclusiones, Vol: 7 num Especial (2020): 538-554.

individual and its manifestation in critical situations[3]. These situations are determined by quite complex mental states of an individual[4]. We find the empirical studies of mental states of expectations, *anticipation* and mental resources of an individual in different activities, including sport and competition activities, to be of great scientific value.

Currently a number of studies prove the importance and topicality of developing this tendency, determining the vector of formation of scientific knowledge aimed at generalizing the data collected in this area. Obtaining objective results in generalizing such groups of indexes has great social importance. The experiments and adequacy of the applied mathematical models[5] give reasons for thinking that this tendency attains a deeper scientific view on the structural transformation of the obtained scientific results in the research on psychology of an individual's *anticipation* and expectations. Therefore, involving an increasing number of factors into the methodology of the research issue requires that the scientific society should apply new and nonstandard approaches aimed at reinforcing the structure of the scientific idea, revealing its new characteristics and the possibilities of investigating and using the obtained results in practice.

Problem statement. It should be assumed that modern psychology is mainly based on statistical research methods providing sufficiently objective results and grounds to confirm the proposed scientific hypotheses[6]. A vast scope of dissertation studies was oriented to using mathematical analysis, logic and set theory[7]. We should also take into consideration a number of studies oriented to applying fuzzy systems and random stochastic processes, the interaction with expert systems[8]. The results of these studies have contributed to the development of psychology for the past decade and have shown practical results.

However, despite the outlined achievements it is necessary to take into consideration the fact that the specificity of an individual's *anticipation*s and the analysis of mental states of expectations as an independent subject area is

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[3] I. Popovych; A. Borysiuk; L. Zahrai; O. Fedoruk; P. Nosov; S. Zinchenko y V. Mateichuk, "Constructing a Structural-Functional Model of Social Expectations of the Personality". Revista Inclusiones, Vol: 7 num Especial, (2020): 154-167 y I. S. Popovych; V. V. Cherniavskyi; S. V. Dudchenko; S. M. Zinchenko; P. S. Nosov; O. O. Yevdokimova; O. O. Burak y V. M. Mateichuk, "Experimental Research of Effective "The Ship's Captain and the Pilot" Interaction Formation by Means of Training Technologies". Revista ESPACIOS, Vol: 41 num 11 (2020:) 30.

[4] R. S. Lazarus y S. Folkman, "Stress, appraisal, and coping". (New York: Springer Publishing Company. 1984) y P. S. Nosov; A. P. Ben; V. N. Mateichuk; M. S. Safonov, "Identification of "Human error" negative manifestation in maritime transport". Radio Electronics, Computer Science, Control, Vol: 4 num 47 (2018): 204-213.

[5] Van Zandt, T. y Townsend, "J. Mathematical Psychology". (New York: Springer Publishing Company. 2012).

[6] S. Scholtz; W. Klerk y L. De Beer, "The Use of Research Methods in Psychological Research: A Systematised Review". Frontiers in Research Metrics and Analytics, Vol: 5 num 1 (2020): 01.

[7] A. Musau, "The Place of Mathematical Models in Psychology and the Social Sciences". The American psychologist, num 69 (2014): 632-633.

[8] G. Kushwaha y S. Kumar, "Role of the Fuzzy System in Psychological Research". Europe's Journal of Psychology, num 5 (2009): 123-134.

complexly formalized, it submits to structuration to a small degree since it deals with a great number of concepts and processes having linguistic descriptions.

It indicates to the problem of the need for new approaches of complex structured methodology for the issue under study, and also formal and visual notions as mental states of an individual. This fact implies generation of a fundamentally new idea and its vector is reflected in this study. In order to solve this problem, it is necessary to examine the existing formal theories capable of describing the methodology of *anticipation* in an integrated way.

Therefore, the purpose of the study is to develop a fundamentally new formal approach to creating a map of negative *anticipation* of captains aimed at preventing disastrous consequences on maritime transport caused by a *human factor* (maps of negative *anticipation* of captains (MNAC)).

Literature review

In order to achieve this purpose, it is necessary to examine main characteristics of the subject area that should be reflected in a new formal approach. The immediate construction of MNAC is possible when a certain formal instrument allows determining its structure and parameters in in the given metric space. It should be taken into account that it is impossible to obtain information about an individual's *anticipation* without the means of the methodology under study. They allow creating MNAC in a new formal space with the axioms and functions characteristic of it.

In the course of monitoring and analyzing the experimental data on sea captains' keeping watch, there were preconditions to draw conclusions that the emergence of *anticipation* has a crucial impact on an ultimate result and mostly depends on a mental state of expectation[9]. These facts manifested themselves indirectly, mainly, at the moment of captains' performing difficult maneuvers in the situations close to critical ones. After conducting experiments, the subsequent discussion of the main principles of the captains' behavior made it possible to draw a conclusion that their purposeful mental activity was accompanied by complex *anticipation* processes. As a result, in some cases the anticipated professional future added an undesirable effect. For instance, in the course of mooring operations[10] a group of captains consciously chose a behavioral strategy not causing a positive result. That fact made the captains change the plans of their actions missing essential factors when planning difficult maneuvers because

[9] I. S. Popovych; O. Ye. Blynova; M. I. Aleksieieva; P. S. Nosov; N. Ye. Zavatska y O. O. Smyrnova, "Research of Relationship between the Social Expectations and Professional Training of Lyceum Students studying in the Field of Shipbuilding". Revista ESPACIOS, Vol: 40 num 33 (2019): 21.

[10] P. S. Nosov; S. M. Zinchenko; I. S. Popovych; A. P. Ben; Y. A. Nahrybelnyi y V. M. Mateychuk, "Diagnostic system of perception of navigation danger when implementation complicated maneuvers". Radio Electronics, Computer Science, Control, 2020, Vol: 1 num 52 (2020): 146-161 y P. Nosov; I. Palamarchuk; S. Zinchenko; I. Popovych; Y. Nahrybelnyi y H. Nosova, "Development of means for experimental identification of navigator attention in ergatic systems of maritime transport". Bulletin of University of Karaganda. Technical Physics", Vol: 1 num 97 (2020): 58-69.

of lack of time to perceive the situation objectively. It is caused by the fact that a captain, modeling the forthcoming satisfaction of the need in his conscious, voluntarily or not motivates his choice neglecting the integrity of the surrounding information signals[11], that reduces safety of navigation.

The outlined problem has also been examined in a number of studies, that allows considering it as objectively existing and requiring the development of adequate methods to solve it. One of the difficulties on the way to achieving the purpose of the research is the above-mentioned difficulty of formal-logical representation of the data and information about the fact of the emergence of *anticipation* with a negative effect.

Taking into consideration the aims of the paper we suggest comparing the principles of the systemic approach, that are important in developing the concept of identifying captains' *anticipation* and the levels of formalization of the suggested approach in Tabl. 1.

Principles of the systemic approach	**Principles of creating formal systems**
1. Systemic-elemental or systemic-complex – all the structural elements of the phenomenon under study are distinguished and split into smaller structural elements. Each element enters a cycle of homogenous elements, oriented towards the achievement of a certain research purpose.	Each operation – action / dimension of an individual's *anticipation* (Action/An individual's *anticipation*, A/IA) must be strictly defined both formally and within the framework of this metric space as a unit element of the system. This element of the system must also have the property of cyclicity and be inseparable from the system.
2. Structuration allows analyzing the elements of the system and their correlations within the framework of a certain organizational structure in random order. The process of the system functioning is determined by not only the properties of its structural elements, but also by the properties of the structure itself.	Operations within the framework of a certain organizational structure have equivalent character and the order of applying them cannot be severe. Operations can be regrouped into the chains A/IA that will not break its integrity and effectiveness.
3. A property – internality – has an impact on all the structural elements of the above-mentioned component on the whole, and, in particular, on self-esteem and estimation of one's	The availability of the primary element in the form of the initial and, at the same time, ultimate operation in the case of a cycle that does not change the state of the research structure, but

[11] S. M. Zinchenko; P. S. Nosov; V. M. Mateychuk; P. P. Mamenko; O. O. Grosheva. "Automatic collision avoidance with multiple targets, including maneuvering ones". Radio Electronics, Computer Science, Control, num 4 (2019): 211-221 y S. Zinchenko; P. Nosov; V. Mateichuk; P. Mamenko; I. Popovych y O. Grosheva, "Automatic collision avoidance system with many targets, including maneuvering ones". Bulletin of university of Karaganda, Vol: 96 num 4 (2019): 69-79.

actions; a property – adequacy of self-esteem and estimation of one's actions, affecting the level of social expectations of personality and its *anticipation* as a consequence.	it serves as a starting point and determines the vector of distributing other operations and also connects the sets of operations in the trajectory A/IA with each other.
4. Complex trials, in the processes of which, as a consequence of replication of the trials of objects on the whole, general regularities about the characteristics of quality and reliability of these objects are revealed. However, if a structural element does not lead to expected results again, then the trajectory of the research implies the return to the initial point.	The availability of operations with a negative sign, implying the return to a preceding operation or the transfer to a new metric space, but not within the framework of the initial formal system. The function of preventing the recurrence of unproductive decisions also manifests itself in this way saving time and resources of the system.
5. Systemacy consists in the fact that the object must have all the characteristics of the system, implying a set with an initial stage (element). An initial stage of any systemic research is investigation of the object of systemic analysis with its subsequent formalization. And a final stage is the best alternative according to the accepted criterion of evaluating the quality of the achievement of the purpose.	The availability of a finite and certain number of operations – a set, related to an initial operation as the starting point of the trajectory. It predetermines the factors included into the system, the so-called generatrixes that do not allow the system to deviate from the purpose. The trajectories A/IA formed in this way will have a logically grounded structure, arranged according to basic principles.
6. Integrity allows considering the system as a single unit and as a subsystem for higher levels at the same time. And an individual's *anticipation* and expectations are considered as the processes of mental regulation of an individual's behavior.	Combinations of operations allow making chains and a successive algorithm of activating them forms the trajectory of A/IA. The data of the trajectory may have a closed structure thus determining the complete cycle of the stage A/IA.
7. Hierarchy of construction, i.e. the availability of a great number of elements, in particular, not less than two elements, located on the basis of subordination of the elements of a lower level to the elements of a higher level. Any organization is interaction of two subsystems: managing and being managed. One is subordinate to the other.	Operations are organized into sets, and the sets form the trajectories, created according to the initial principal of formation. The generatrixes of these trajectories are based on the principle of its formation and determine the structure and combinations of the components of its elements and the system of generatrixes.

8. Multiplicity allows applying an unlimited number of scientific models and operations of research character.	The trajectory consisting of the sets of operations is not limited in its spread relative to the accepted metric of the space.

Table 1
The principles of developing the concept of *anticipation* in the context of the approach to the formation of a metric space

The analyzed connections between the principles of the systemic approach of the psychology of expectations, identification of *anticipation* and the principles of creating formal systems allow determining the resemblance and identity of the notions and processes that enables us to continue scientific search to achieve the re-search purpose.

For instance, in order to determine an elementary formal system it is enough to determine its following components: finite aggregate of the elements; finite aggregate of combinations of the elements; commutativity of combinations of the elements; symbols of implication and punctuation for structuring the elements and their combinations; axioms of the system determined by formulas and variables.

Materials and methods

Continuing our scientific search we will determine the correspondence between the outlined principles and the structure of the elementary mathematical system, the obligatory elements of which are the following: an alphabet or the totality of objects representing the mathematical system; multitude of words or combinations of objects being axioms; finite aggregate of relations or operations with the objects; theorems or rules of conclusion – the result of solvability.

According to the theory of formal and mathematical systems[12], the outlined principles are sufficient to deal with formalization of such a multifaceted subject area as modeling of respondents' expectations and constructing MNAC.

Taking into account the research purpose and also the necessity to visualize the results of mathematical modeling, we maintain that geometric group theory is close to the description of the above-mentioned principles. This theory is represented as an independent one, deriving from the theory of groups and giving a wide range of possibilities of visual presentation of its properties within a strict framework of formal transformations.

It is necessary to mention that groups make it possible to determine the so-called symmetry, the balance of a formal system[13], that is very important for

[12] H. Kyburg y R. Smullyan, "Theory of Formal Systems". The American Mathematical Monthly, num 71 (1964): 937 y A. Rantzer y C. Byrnes, "Directions in Mathematical Systems Theory and Optimization", The American Mathematical Monthly, Vol: 3 num 540 (2003) 16-26.
[13] T. Al-Noor y O. Al-Obaidi, "The course of lectures on Symmetry and group theory". 2013.

arranging structural principles in the formation of the model of a captain's *anticipation*. We will examine its main axioms:

1. Closure of a group. There is a third element for any two elements of a group that is their product, the one that (1):

$$\forall a,b \in g: \ \exists c \in g, \ \ a \circ b = g \tag{1}$$

The axiom corresponds to Points 6 and 7 (see Tabl. 1), describing integrity, complexity and hierarchy of creating the trajectory A/IA, consisting of the elements and operations of steering a vessel.

2. Associativity of a group for operations of the product. The order of operations is not important (2):

$$\forall a,b,c \in g: \ \ a \circ \left(b \circ c\right) = \left(a \circ b\right) \circ c = a \circ b \circ c \tag{2}$$

The axiom corresponds to Points 1 and 2 (see Tabl. 1), within the framework of systemic-elemental and systemic-complex principles, where the cycle of homogenous elements is directed at achieving the ultimate purpose of navigation.

3. The existence of a unit element. In the group there is a certain element e, the product of which with any element of a group produces the same element a (3):

$$\exists e \in g: \ \ \forall a \in g, \ \ a \circ e = e \circ a = a \tag{3}$$

The axiom corresponds to Points 3 and 5 (see Tabl. 1), in which internality implies an impact on all the structural elements, possessing all the signs of the system, derive from the initial element in the form of the initial operation, determining the trajectory A/IA. The initial strategy, chosen by a captain, predetermines its effectiveness.

4. The existence of an inverse element. For any element of a group there is such an element a-1, that their product produces such a unit element e, that (4):

$$\forall a \in g: \ \ \exists a^{-1} \in g: \ \ a \circ a^{-1} = a^{-1} \circ a = e \tag{4}$$

The axiom corresponds to Points 4 and 8 (see Tabl. 1), implying the repetition of the operations of steering a vessel, i.e. of their reverse functions, presupposing the return to its beginning. This operation does not restrict the trajectory A/IA according to the principle of multiplicity that allows applying an unlimited number of operations on the part of a captain.

Taking into account the above-mentioned information we can state that axiomatic description adequately coincides with the basic principles of the

psychology of a captain's expectations, within the framework of manifestation of his *anticipation*. There is a possibility to examine the principles of the formation of MNAC in terms of geometric group theory.

We will use the word "alphabet" to designate the finite aggregate of the research stages having different initial principles, that:

$$A = \begin{Bmatrix} a, & b, & c \\ a^{-1}, & b^{-1}, & c^{-1} \end{Bmatrix},$$ where a^{-1}, b^{-1}, c^{-1} – the inverse alphabet according to p. 4. We will use the word "group" to designate the formal construction of the type $\langle A \mid R \rangle$ where R relations between the sets of operations leading to the unit element, for instance: $\langle a,b,c \mid a^2 = b = c^4 = e \rangle$[14]. For example, the set of elements a^x will have its own orientation of an individual's actions, correspondingly b^y and c^z are different from the first one. The totalities of sets can be represented as sub-trajectories combining into words, such as $a^4 b^6$ etc. but operating with combinations within the alphabet of the group.

We can distinguish two variants in terms of groups, a commutative group and a free group, also having a meaning in the methodology of social expectations of personality and *anticipation*:

$\langle a, b \mid \rangle$ – a free group, having no words – i.e. strict directions of the formation of the trajectory, but only principles. It is characteristic of those situations that are at the initial stage of captains' professional activity and, as a result, have no strictly specified behavioral stereotypes developed in the course of time.

$\langle a, b \mid ab = ba = e \rangle$ – a commutative group – i.e. the group where the axiom of associativity is evident, however, its form can be more complicated: $\langle a, b, c, d \mid ab = ba = c^3 = ad = d^7 = e \rangle$ and be determined by a number of other axioms. The words formed represent independent trajectories that can be composed of basic elements of a captain's behavior. We can see in the example that the connective $ab = ba$ can be used in any combination; the element c^3 implies the use of a certain strategy of behavior three times; e – the single operation common for all the trajectories of a captain's behavior, coming from it and returning to it to pass later to a new stage of steering a vessel.

Visual reflection of the trajectories is the most obvious method in this approach that will allow presenting the above-mentioned properties in a more

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[14] S. Glasner, "Topological dynamics and group theory". Trans. Amer. Math. Soc., num 187 (1974): 327-334.

unified way. To solve this task, we will use geometric group theory where each element of the trajectory represents a point in a metric space[15].

The connection of the points in the space allows creating a graph, and it should be accepted that the formation of a graph edge is possible only if the subsequent element derives from the preceding one by means of multiplication by one letter of the group. For instance, g1 and g2 are connected by the edge, if $\exists a \in A;\ g_1 = g_2 \cdot a \Leftrightarrow g_1 \cdot a$ in the alphabet. It means, if all the elements of the graph are generated by means of a multitude of generatrixes words, then the graph will be connected, i. e. the geometric group constructed in this way is the unknown metric space.

Therefore, there is a necessity to construct a metric space within the framework of identifying a captain's *anticipation*, as a real example with practical application.

Experiments

Taking into account the above-mentioned facts, we conducted an experiment using a certified navigation simulator "Transas navigation simulator NTPRO 5000" in Kherson State Maritime Academy (Ukraine).

To conduct the experiment, we selected a group of 54 sailors-navigators who acted as captains in the training courses applying Electronic Chart Display & Information System (ECDIS) to navigate and steer a vessel. We analyzed the models of the captains' behavior when sailing through the Bosporus strait (Turkey) that has quite high-density traffic and hydrographic challenges. Before the beginning of the experiment each captain started with planning the route, examining maps, weather conditions and the vessel characteristics.

In the course of the experiment the captains created their own trajectories of behavior in the given environment operating two strategies of navigation: managing the speed of the vessel and the rudder blade. In most cases the given sections of the vessel route, requiring a choice of strategies, emerge fragmentally throughout the entire route[16]. Therefore, for the time of the expedition, the captains formed a number of the given fragments of the trajectory, each of them being a chain of events with a different order of strategies.

In that way the captains operated two basic strategies a and b, thereby there was a possibility to present a reflection of the trajectory of the captains' behavior in a metric space geometrically. We will represent this situation as the group: $G = \langle a, b \mid \rangle$, where there are no commutating elements. The generatrixes of the group also have negative values: a-1 и b-1. And if the positive elements, a

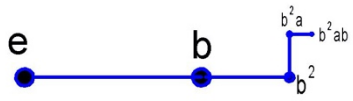
[15] A. Malyutin, "Geometric group theory". (Sankt-Peterburg: Smysl. 2020).
[16] D. S. Moon; D. J. Kim y E. K. Lee, "A study on competitiveness of sea transport by comparing international transport routes between Korea and EU". Asian Journal of Shipping and Logistics, Vol: 31 num 1 (2015): 1-20 y M. Barus; H. Asyrafy; E. Nababan y H. Mawengkang, "Routing and Scheduling Optimization Model of Sea Transportation". IOP Conference Series: Materials Science and Engineering, Vol: 300 num 012011 (2018): 1-7.

and b – are the actions on the part of the captains, than the negative elements a-1 and b-1 – are the manifestations of their *anticipation* and self-expectation. This approach will allow solving the task of constructing MNAC in an integrated way.

Taking into account these ideas we will present a visual reflection of the captains' behavior as Kelly's graph (see Fig. 1). In order to avoid the intersection of the graph edges we will reduce their scale at each stage of its visualization.

Examining the entire metric space depicting Kelly's graph, we can see that the space of variants is full. The detailed analysis of the models of the captain's behavior in the course of the experiment showed that the graph reflects the dynamics of the trajectories of their behavior in more than 79.0% of the cases.

For instance, in an individual case, the fragment of the trajectory of the captain's behavior with two strategies had the following form:



It is obvious in this case that the strategy b was chosen initially, b2 was repeated in view of a possible success, however, b2a was further used and again there was a return to the initial strategy b2ab. This strategy corresponds to an intuitive or automatic approach, characteristic of captains without any experience.

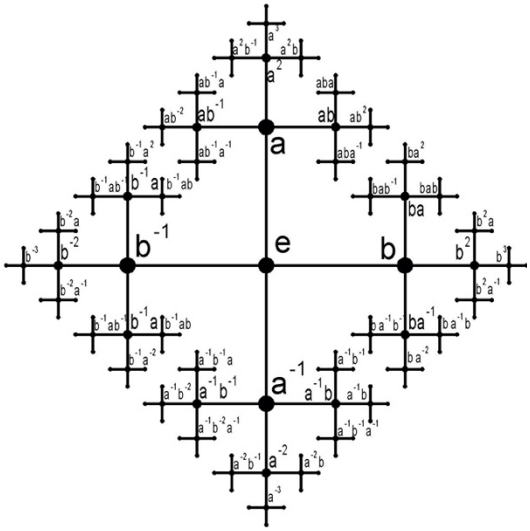


Figure 1
Kelly's graph of the captain's behavior

However, we noticed that a number of reversible actions with a different polarity, relative to the generatrixes, change the current point on the graph in the way that cannot be depicted on the fragment of the trajectory. It is true of those cases when the vector of the trajectory of behavior is directed along one of the axes and changes its direction to the opposite one at a certain time. Considering the axioms of the theory of groups we have a product leveling the finite fragments of the trajectory. For instance, being in the point b-1ab-1 and moving to the action b we lose the latter two fragments and have b-1a instead of b-1ab-1b.

Identification of this type of the captains' manifestations became possible due to the creation of a program module, determining speed and direction of the rudder blade of a vessel in real time excluding emergency turns[17].

We can see in Figure 2 that there were the zones responsible for accepting a certain strategy of the captain along the trajectory of the route, making it possible to classify probable variants of the events. It plays an important role in determining a negative manifestation of a *human factor* in critical situations on maritime transport[18].

However, we noticed in the course of the experiment that an important fact was not taken into consideration, namely, the move from *anticipation* to action along the generatrix, a or b in a reversible direction characteristic of a certain captain. All the fragments of the trajectories, such as: b-1b and a-1a, indicate to the captain's *anticipation*, and b b-1 and a a-1 indicate to unconscious actions, proving his *anticipation*, also generating a polar set of points.

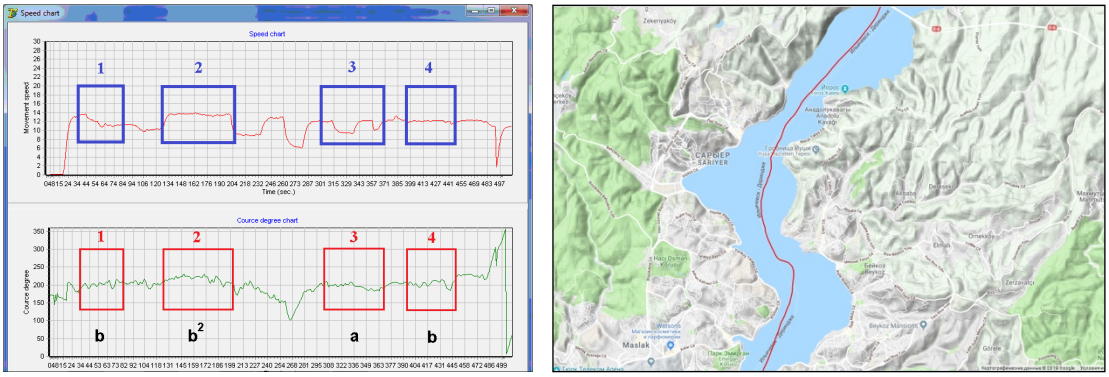


Figure 2
Analysis of technical parameters of the trajectory of the vessel route

In other words, in the course of the experiment we registered such cases both at the time of analysis of the trajectories and observation and a further psychological dialogue with the captains.

Such extrema create an individual MNAC as an additional and rather uneven layer of pseudo-metrics. We will add a third axis to reflect it (see Fig. 2).

[17] S. Zinchenko; A. Ben; P. Nosov; I. Popovych; P. Mamenko y V. Mateychuk, "Improving Accuracy and Reliability in Automatic Ship Motion Control Systems". Radio Electronics, Computer Science, Control, num 2 (2020): 1834-195.
[18] R. Puisa; L. Lin; V. Bolbot y D. Vassalos, "Unravelling causal factors of maritime incidents and accidents". Safety Science, num 110(A), (2018): 124-141.

Taking into consideration the specificity of the subject area, we should mention that these cannot be equal. It is more logical to assume that it is reasonable to determine the resultant index of the captain's expectations in each immediate point of MNAC. Thus, the relative value of this index within the range of 1–10 will be the desired measure of extremum, the distance from the plane of the graph to the point (see Fig. 3).

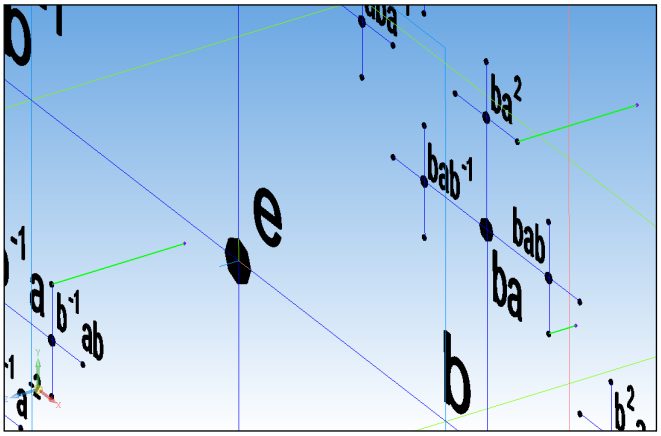


Figure 3
The formation of the points of MNAC

The axiom of commutativity is true only at the first stage of the creation of MNAC since this group is free, the discovered extrema form the words in a new group that is not free any more in view of the points of MNAC.

Conclusions

This approach allows presenting a geometrically determined MNAC that makes it possible to find individual relationships between the manifestations of *anticipation* characteristic of each captain.

The given MNAC allows solving the problems of identification of captains' *anticipation* at a qualitatively new level in modern psychology and revealing the hidden mechanisms of their transformations, arranging complex and multi-parametric mental states of an individual.

A complex approach showed that there is a correlation between the research objects within the framework of an individual's *anticipation* and expectations and formal systems of geometric group theory. The application of information technologies proves the research results and allows projecting the conclusions onto a wide range of problems of personality psychology, identification of vessel captains' *anticipation* in critical situations, in particular.

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