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Systemogenetic Patterns of Development of Cognitive Determinants of Information-Related Activities

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Abstract

Introduction. At the present stage of social development, the study of computer-related information activities and the identification and explanation of their subjective determinants as important professional characteristics are particularly important. Objectively, it is first necessary to give priority to the disclosure of the role of the cognitive qualities of the subject underlying the organization of these activities, as well as their genesis during the professionalization of the individual. To our knowledge, this study is the first attempt to identify and interpret new patterns of professiongenetic dynamics of basic cognitive qualities and show its belonging to the systemogenetic type of development. **Methods.** The sample (n = 230) comprised programmers of various profiles and levels working in organizations in Yaroslavl, Moscow, and Rybinsk. Psychological assessment was performed using traditional, most valid assessment instruments for components of the cognitive subsystem, as well as a number of techniques developed by authors. The methodology for structural and psychological analysis has also been implemented. **Results.** The dynamics of the development of basic cognitive qualities in the professionalization process is characterized by a combination of their transformations at two levels – analytical and structural. At the first level, there are changes in the degree of severity, that is, the development of individual cognitive qualities. At the second level, considerable changes occur in the organization of their entire system. In the most general and fundamental terms, the entire complex of established patterns indicates that the professionalization process of IT specialists is caried out according to the systemogenetic type, i.e., it represents the systemogenesis of information-related activity. **Discussion.** The results are interpreted from the perspective of the theory of activity systemogenesis, as well as

the psychology of professional activity of the information-related type. The development process of this activity during professionalization, taken in the perspective of one of the most important categories of its subjective determinants (basic cognitive qualities) is more deeply explained, since its subordination to the basic principles of systemogenesis is explicated.

Keywords

subjective determinants, cognitive qualities, programmer activities, information-related activity, professiogenesis, cognitive subsystem, cognitive processes and operations, systemogenesis

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Introduction

Two important problems occupy a special and largely decisive position in the enormous complexity of new tasks and research directions due to the widespread use of the subject-information class of activities. The first is the need to establish and further study the subject determinants that determine the procedural properties and effective parameters of the activity and are defined in the concept of important professional qualities. The second is the need to disclose the basic characteristics and patterns of formation of this class activities in the professionalization process, i.e. during professiogenesis. Both of these problems are characterized by a combination of high theoretical and practical importance with a clearly insufficient level of development, which is manifested, in particular, in their following aspects. Therefore, as regards the first one, the following can be stated. Despite attempts to establish the complex of PIQ activities of this class, there is still no generally accepted version and, moreover, justified with a sufficient degree of correctness. One of the main reasons is that this class of activity is exactly the class that synthesizes a wide range of activities that are quite heterogeneous according to a number of criteria, i.e. types of information activity. However, it is obvious that as a qualitatively specific

class, it is characterized by a sufficiently pronounced invariance of basic psychological characteristics and, accordingly, requirements for the sphere of subjective determinants, which requires the identification of this invariant "core". For example, the most well-known lists of this kind can be noted as follows: the ability to solve problems, an analytical mindset, perseverance, the ability to work in teams, good concentration, assiduity, an algorithmic approach, responsibility, sociability, and initiative (Plotkina, 2010). There are other versions of them, presented, in particular, in the works (Kuznetsova & Skrylnikova, 2017; Orel, 2007; Husenov, 2020; Connolly et al., 2016; Weinberg, 1971).

The main feature of the current state of the second problem is the insufficient level of its theoretical elaboration and, accordingly, emphasized pragmatism. This manifests itself, in particular, in a larger number of specific procedures and training programs that are primarily empirical and purely applied in nature, for example: Skillbox, Netology, ProductStar, Yandex Practicum, Skypro, Hexlet, GeekBrains, etc. (Alison, 2015; Attrill & Fullwood, 2016; Carter et al., 2020; Wyeld, Calder & Shen, 2013). Of course, this itself is absolutely necessary at a particular stage of its development, which, however, not only negates but also prescribes the need to address its theoretical aspects at other subsequent stages of its development. One of the most important is the definition of the patterns of genesis of information activity and personality.

We believe that when trying to understand these problems in this theoretical way, the following very important circumstances should be taken into account, which at the same time should serve as methodological guidelines for their study, including for what is presented in this paper. Firstly, we should start with the fact that the very concept of PIQ is fundamentally functional, i.e. it synthesizes all these subjective determinants that act in an identical function – as determinants and factors contributing to the effective implementation of activities. Their roles may be very different, heterogeneous in many respects, qualitative, and not only psychological. In this respect, this concept can also be considered as an umbrella term that combines functionally variable characteristics of the subject. This is exactly the case with regard to the subject-information class, manifested, for example, in the fact that two groups of qualities are differentiated as PIQ in relation to it – psychological qualities proper and the so-called "skills" (Demidenko & Yeratina, 2021; Karpov, 2024a, Karpov et al., 2024b; Dori, Mevarech & Baker, 2018; Yzerbyt (ed.), 2002; Sajaniemi, 2008). They are also divided into two subgroups, which are also very different in content – hard skills and soft skills. The first are primarily activity-driven, while the second are personality-driven. At the same time, in the whole complex of PIQ of this activity, there are also such qualities that are a kind of "nuclear" – they do not just affect the activity or even determine its effectiveness, but act as operational means of its implementation. This is especially evident in the most representative activity of this class – in the activity of programmers, which was the subject of research in this paper.

Indeed, in relation to it and many other types of activities included in this class, the following important features can be explained. In all its attributes and, in general, in almost all its substantive and structural characteristics, this activity not only closely

approaches what is usually referred to as its internal plan – as the structure and content of mental regulation, but also practically reduces to it. This activity in many or even almost all of its main aspects passes into the internal plan, and its structure and content become fundamentally similar to the structure of mental regulation. What acts as its regulator and therefore only as part of it in relation to all other types and kinds of activity in relation to this class becomes the whole activity – at least in its attribute characteristics and the main operational means of implementation. Consequently, the structure of the activity of the subject-information class and, accordingly, the complex of its PIQs largely repeats or even reproduces – multiplies – the structure of mental regulation. Therefore, the establishment of their entirety can and must be based on the content and composition, as well as on the structural organization of this regulation. However, for completely natural reasons, the leading and decisive role in ensuring this regulation is occupied by the cognitive subsystem of the whole psyche – in the whole complex of processes and mechanisms that form it, as well as by other operational means. This activity as a whole is almost entirely information-related. It is also important that the main attribute of this activity is its object, namely information, which again determines the crucial role of these processes and mechanisms in its supply, and its fundamentally cognitive nature. In this respect, one of the slogans of the IT industry is indicative: "The work of programmers is solving problems" (Attrill & Fullwood, 2016).

Due to these circumstances, it is even more difficult to identify the PIQ activities of this class, since their entire sphere is transposed into the internal plan. They are specifically represented in the intrapsychic plane and are therefore much less explicit and accessible for any research procedure. However, it is precisely this circumstance that makes it easier to identify the PIQ of this activity to a very significant extent. Since, as noted, the content – the composition and structure – of PIQ in it is the cognitive support of activity itself as the basis of its mental regulation and organization as a whole, the cognitive subsystem of the psyche is exactly the bearer of this content. Therefore, the components that are included in it – basic cognitive processes and qualities – are the main components of this activity. This is determined by the congruence and practical isomorphism of the content and composition of the activity as a whole, on the one hand, and the mental regulation implemented on the basis of its cognitive support, on the other. The cognition itself and its highest level, the thinking process, takes an active form and, in fact, becomes largely this activity, and the activity is almost completely cognitivized and realized as the function of the cognitive subsystem of the psyche.

Further, when substantiating the theoretical approach to the development of the second of these areas – professiogenetic – it is necessary, in our opinion, to rely on the results of a fairly extensive research cycle of theoretical, methodological and activity-analytical plan, carried out by us earlier. In the course of its implementation, the position was substantiated and implemented, according to which the most constructive methodological approach to the study of the occupational genesis of activities of this class is the concept of the *system-genesis* of activities. It was successfully implemented

earlier in relation to many activities of the other two classes (subject-object and subject-subject) (Karpov, 2021; Karpov & Shadrikov, 2017). As a result, the occupational genesis of two major subject determinants – basic *metacognitive personality traits* and a complex of *professional competences* – was studied in relation to them (Karpov, Karpov, & Prisyazhnyuk, 2024; Karpov, 2021). At the same time, on this basis, not only the possibility opens up, but also the need arises that their qualities are supplemented by another, to some extent, defined group – a group of cognitive qualities, a group of their complex, i.e. in their structural organization – as components of the cognitive subsystem of the psyche. Moreover, for obvious reasons, it should also be implemented based on the methodology of the system-genetic approach.

The main objective of the research presented below is therefore to investigate and explain the characteristics of the formation and development of the complex of cognitive qualities as determinants of information activity based on the concept of system-genesis.

Methods

The following main problems must be solved in order to organize research.

Firstly, this is a problem related to the fact that the subject-information activity itself is characterized by a high degree of heterogeneity and therefore the question arises as to which specific type of activity is most representative in relation to the whole and should therefore be investigated first of all. As shown by our analysis of this issue in (Karpov, 2021), as well as in (Kuznetsova & Skrylnikova, 2017), it is the activity of programmers that is the most complex and rich in psychological content. This is why it was used as the basis for this study.

Secondly, it is the task of determining the totality of the most important and representative cognitive practices of this activity. Based on the theoretical provisions formulated above, its solution should be carried out as follows. First of all, their complex should represent the cognitive subsystem as a whole and therefore include qualities related to the main cognitive *processes* – first of all, of course, the main and hierarchically higher of them, i.e. thinking. Furthermore, this complex should include qualities related to the basic – core – operational components of cognitive processes, i.e., to their actual *operational composition.* At the same time, it should be taken into account that it is the operational composition of any process, and especially thinking, that forms the basis of its qualitative certainty and acts as a bearer of its specific content. For this reason, it is necessary to include in the complex of the studied qualities those that relate to the basic operations of thinking itself – with the operations of analysis and synthesis, abstraction and concretization, etc.

Finally, these two circumstances, combined, allow for the implementation of another important requirement. It consists in the fact that this complex should contain components (in this case, cognitive PIQs) that differ significantly in their degree of complexity and level

of localization. This allows us to take into account an important feature of the cognitive subsystem – its multidimensionality and qualitative heterogeneity. In this regard, their entire complex was divided into two groups. The first included cognitive qualities related to the level of the processes as a whole, and the second – to the level of their operational content, i.e. with individual operations. The first group included the following qualities (with instruments for their assessment). First of all, these are the three main qualities of the basic cognitive process of thinking, including analyticity, abstractness, and practicality. Analyticity was determined by the Raven Progressive Matrices Test, and abstractness and practicality were determined by V. A. Hansen assessment instrument (Hansen et al., 2001). Further, the ability to operate with two–dimensional spatial images was diagnosed as an important quality of the imagination process (based on the subtest Geometric Addition – GS, Amthauer Intelligence Structure Test (Intelligence Structure Test, 1996)). Another cognitive process, attention, was assessed using the F. D. Gorbov diagnostic instrument to manometrically identify the main properties of attention – distribution, volume, switchability, and stability (Gorbov & Lebedev, 1975). Finally, an individual measure of the severity of another important cognitive quality correlated with another major cognitive process (memory) – visual working memory – was determined (using G. N. Khilova assessment instrument (Khilova, 1975)).

There are much more difficulties in diagnosing the second group of qualities – those related to cognitive operations. The fact is that individual operations revealed as part of a particular cognitive process are virtually impossible to study or diagnose, so to speak, "in their pure" form. There is a problem with "operationalizing the operations themselves" – bringing them into a form that allows them to be studied experimentally or empirically. This difficulty can be minimized by taking into account one of the main principles underlying almost all diagnostic methods of the cognitive sphere in general and intelligence in particular ((Psychodiagnostics: Theory and practice, 1986; ed. by N. F. Talyzin).

It consists in the fact that the performance of any test task involves, of course, relying not only on one or another individual process, but on their totality. However, and this is the essence of this technique, the following important and indispensable condition must be observed. Any individual subtest is designed so that the main functional load when it is performed falls on a specific cognitive process. This can be described as the principle of *functional dominance* of certain processes. This is the basis for almost all intelligent tests. However, the same can rightfully be stated with respect to the study and diagnosis of individual operations. They are also impossible to model or diagnose in their pure form. At the same time, this can be approached by creating conditions in which one or the other of them will functionally dominate. This is exactly what is known to be implemented in one of the most well–founded intellectual tests, Amthauer Intelligence Structure Test, so it was used as the basis for this part of the study. Therefore, the components of the operational composition of thinking (operations) were diagnosed using the following subtests of the Amthauer Intelligence Structure Test:

1. The Logical Selection (LS) subtest evaluating the *inductive* components of thinking.
2. The General Features (GE) subtest evaluating the ability to *generalize* and operate with concepts.
3. The Analogies (AN) subtest evaluating combinatorial abilities and operations by *analogy.*
4. The Pattern Identification (PI) subtest evaluating one of the most famous mental operations, *synthesis.*
5. The Classification (CL) subtest, which focuses on another equally fundamental mental operation, *analysis.*
6. Another basic operation, abstraction, was investigated using the procedure developed by us in (Karpov & Karpov, 2019) for diagnosing the level of basic cognitive operations.

Thirdly, since the study had a profession-genetic focus, it was based on the methodology of comparative study of the degree of formation of cognitive qualities at different stages of profession-genesis. A special review of the literature conducted in this regard showed that, as a rule, three main stages are differentiated in the general process of professionalization of programmers – 1.5 years, 3-4 years and 7 years. It is also important that these three stages are in good agreement with the most traditional differentiation of the main levels of professional qualification of programmers, which also involves the differentiation of three levels – junior, middle and senior.

Finally, since the implemented study was carried out in line with the system-genetic approach, the tools developed in it were applied to its organization and processing of the results. This is a methodology of structural psychological analysis, the essence of which is as follows. It involves the implementation of a multidimensional correlation analysis procedure, which includes a method for determining intercorrelation matrices of the studied parameters (in this case, the main qualities of the cognitive plan); a method for constructing structurograms of significantly correlating parameters; a method for calculating indices of structural organization, the $\chi 2$ test for determining the homogeneity-heterogeneity of intercorrelation matrices. The main indices of structural organization are the structure coherence index (SCI), the structure divergence (differentiation) index (SDI) and the structure organization index (SOI). The first is defined as a function of the number of significant positive correlations in the structure and the degree of their significance; the second is defined as a function of the number and significance of negative correlations in the structure; the third is as a function of the ratio of the total number of positive and negative correlations and their significance (Karpov, 2015).

The *study participants* (n = 230; 155 males, 75 females) were programmers of various profiles and levels (application programmers, system programmers, graphics programmers, database engineers, quality assurance specialists, frontend developers, web developers) living in three Russian cities (Yaroslavl, Moscow, Rybinsk) aged 24 to 61:

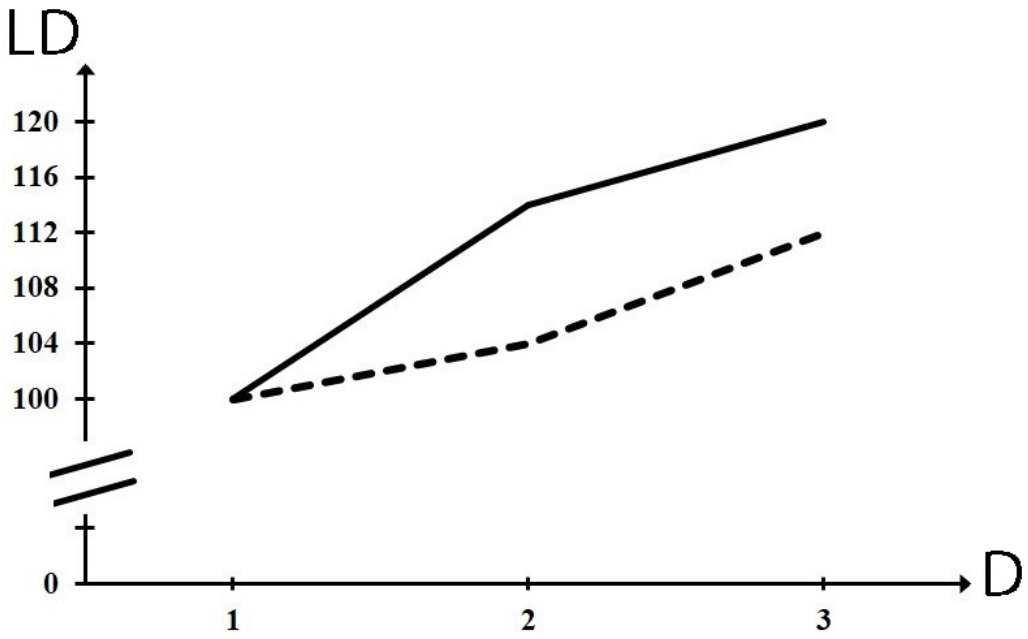
<31 years – 98 subjects (42.60 %), 31-45 years – 92 subjects (40.00 %), > 45 years – 40 subjects (17.39 %).

Results

The first and most general result of the study was to establish a significant increase in the individual level of almost all the cognitive qualities considered to be PIQs in the professionalization process. Furthermore, this applies both to individual qualities and to the two groups of them as a whole (these were, on the one hand, qualities correlated with the main cognitive processes in general, and on the other – with the main cognitive operations). Therefore, this result can be illustrated in the most general form in the following results. Figure 1 shows data on the dynamics of the development of qualities that form two main determinants groups. These data were defined as the average of the sum of diagnostic indicators of all qualities included in each group. The diagnostic indicators of each group of qualities in the first time-related interval, that is, the interval related to work experience, were taken as the initial level, that is, as 100%, and the diagnostic indicators of the second and third stages were calculated in relation to it.

Figure 1

Dependence of the level of development of cognitive processes (solid line) and cognitive operations (dotted line) on work experience

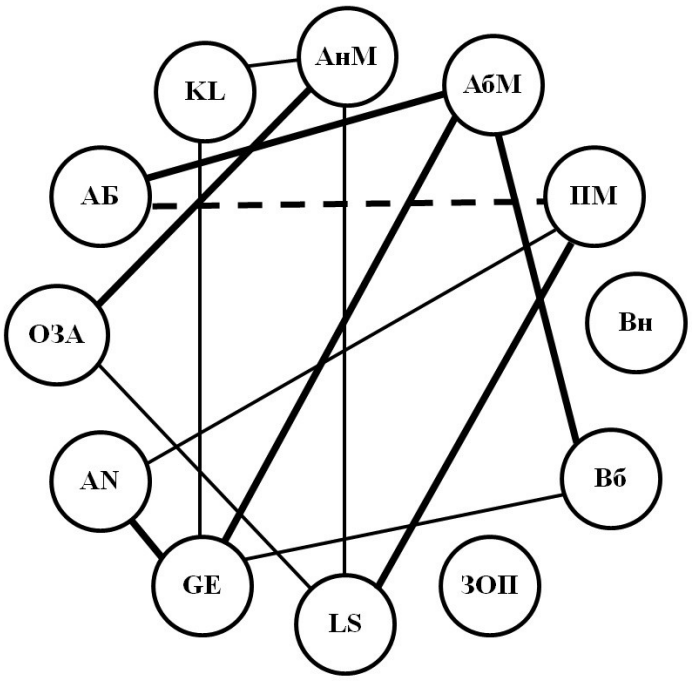


For example, the value of 114% in relation to the group of process-related qualities at the second stage means that the level of their severity increased by 14%. In addition, we should note that in general, a similar dynamics has been found in relation to certain features of the cognitive plan. This means that it is typical not only for the dynamics of the formation of quality groups, but also for each of them individually. At the same time, we should note that this kind of dynamics is very moderate – both in absolute and relative terms. It is significantly less represented than the similar professiongenetic dynamics that we established earlier in relation to other basic types of subject determinants of activity, in particular, professional competencies and metacognitive qualities (Karpov et al., 2024; Karpov et al., 2024a), which requires explanation in further discussion.

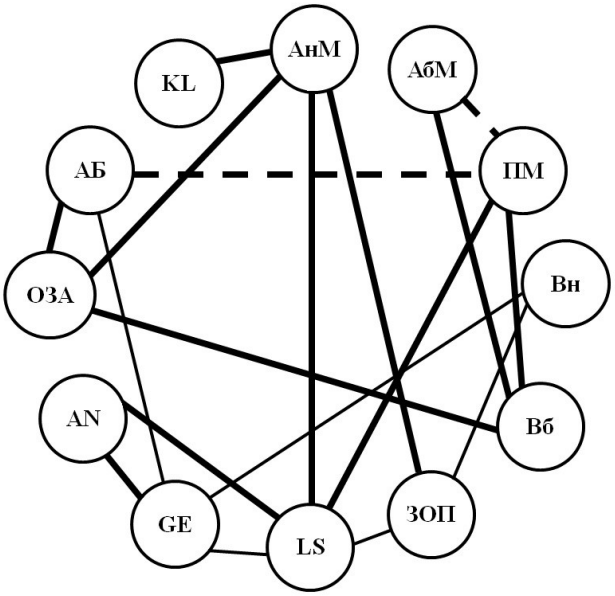
Furthermore, in terms of the results obtained, not the analytical level, but the structural level of research was implemented. It involves determining the structurograms of the subject determinants of activity – in this case, cognitive qualities, as well as their subsequent comparative consideration. Figure 2 shows the structurograms of these qualities for two groups with different work experiences (1.5 years and 7 years).

Figure 2

Structurograms of cognitive qualities



а



b

Note: "a" – 1.5 years *of work* experience, "b" – 7 years *of work* experience; AnT – analytical thinking, AbT – abstract thinking, PT – practical thinking, *At* – attention, *Im* – imagination, *VWM* – visual *working memory,* LS – logical selection subtest, *CD* – common definition subtest, *PD* – pattern definition subtest, AN – analogies subtest, AB – abstraction method, *C*L – classification subtest; bold lines – *correlations* significant at p <0.01, *to* which *a "*weighting" coefficient *of* 3 points *is* attributed; *semi*-bold lines – *correlations* significant at p < 0.05, which *is* attributed *a* coefficient *of* 2 points*;* dotted lines *represent* negative *correlations*. *The* "weights" for all *correlations are* summed *up*, which gives *the* values *of the* structural coefficients.

Table 1 shows data on the dynamics of the main structural indices, which characterize, respectively, the degree of coherence (integration) of the structures found, the degree of their differentiation, as well as their overall organization.

Table 1

Structural indices of the complex of cognitive qualities in three groups with different work experiences

	Work experiences		
	1.5 years	3-4 years	7 years
SCI	30	34	43
SDI	2	2	4
SOI	28	32	39

Discussion

The analysis of the presented results allows us to draw the following conclusions. First, as mentioned above, the dynamics of the revealed cognitive qualities are very moderate, both in absolute and relative terms. It is much less pronounced than the similar dynamics we have established in relation to other – basic – types of subjective determinants of activity. Thus, in absolute terms it changes from the first level of professionalization to the third by 20%. However, with regard to the data obtained, for example, in the works (Karpov et al., 2024; Karpov et al., 2024a) in relation to other determinants, another situation can be observed. In particular, the dynamics of the development of professional competencies – skills – is from 68% (for soft skills) to 123% (for hard skills). The similar dynamics of the development of metacognitive determinants are even more pronounced – they are about 140 %. Finally, in relation to the category of basic individual qualities, which also function as PIQ, it is measured by 40% values. This result, in our opinion, indicates the existence of a significant professiongenetic pattern. It is based on the fact that this dynamic is less pronounced the more general and fundamental qualities themselves are in the organization of the psyche as a whole. Indeed, despite the importance of the subject determinants studied earlier and noted above, they are still obviously inferior in this regard to the totality of cognitive qualities, which manifest the most important – the *basic* operational means of organizing the psyche as a whole – the main cognitive processes. They underlie the entire structural and functional organization of the psyche; moreover, they are not only conditioned by this organization, but they themselves largely determine it. And precisely because of this fundamental nature, they should be relatively more tolerant of external influences, even strong ones such as profession-genetic factors.

Secondly, we can see that the comparative rates of formation of the studied cognitive qualities, that is, the intensity of their formation and development, are different at different stages of the professionalization process. This is particularly evident in the dynamics of the development of the qualities of the first group (related to cognitive processes) characterized by higher formation rates in relatively early stages of professionalization, and in subsequent stages these rates decline significantly. Conversely, the rate of formation of the second group of qualities (related to basic cognitive operations) is moderate in the early stages of professionalization. However, at its more advanced stages, they become much more obvious. Data processing also showed that a similar pattern exists in relation to the comparative dynamics of individual qualities included in these groups. For example, such a very important cognitive quality as analytical thinking develops significantly faster at relatively early stages, and at later stages these rates decline significantly. On the contrary, another important cognitive quality, abstract thinking, is characterized by a relatively low development rate in the initial stages, and then these rates become more pronounced.

Therefore, it is possible to describe an important circumstance: the dynamics of the major cognitive determinants of activity, as well as their groups, as a whole, have an important and general systemogenetic model, which is established on the basis of the *inequality* principle.

Thirdly, as established in the concept of systemogenetic, the *inequality* principle is objectively related to another important and also general principle – the *heterochrony* principle. It is based on the fact that the periods of the most intensive formation of the different "components" of the system, in general, do not coincide; they are "removed" in time. However, this is exactly what is clearly shown in terms of the comparative genetic dynamics of individual cognitive qualities and their groups. It can be seen, in particular, that the periods of the most intensive formation of the first group of qualities (procedural) and the second group (operational) are spaced apart in time – the second is formed much later. Consequently, these features indicate that in relation to the genesis of basic cognitive qualities as subject determinants of information activity, another basic principle of system-genesis is fulfilled – the *heterochrony* principle.

Furthermore, the combined effect of the principles of *inequality* and *heterochrony* determines that there appears to be a *sensitive period* for each cognitive quality and for their complexity. At the same time, the sensitive periods for different groups are at a temporary distance. This shows that the characteristics and patterns of development of significantly different cognitive qualities (process and operation) are also quite different.

Fourth, the data presented in Table 1 sufficiently reveal an increase in the value of the coherence index (SCI) of the entire complex of basic cognitive qualities acting as PIQ in the professionalization process. This means that in the course of professionalization, there is a significant increase in the degree of their integration. The implementation of Kruskal Wallis tests in relation to these data confirms the statistical reliability of the data presented on SCI dynamics ($p < 0.05$). However, we should note that the degree of such an increase is expressed to a lesser extent than it was previously established in relation to other subject determinants of information-related activity (metacognitive qualities, as well as a number of individual qualities acting as PIQs). If the increase for them was measured in multipliers – in "times", then in relation to the dynamics of cognitive qualities, it is measured, albeit significantly, but only as a percentage (by 43%). This circumstance can be explained as follows. The fact is that in relation to the profession-genetic dynamics of the cognitive subsystem, it cannot be said that it is precisely formed and then developed and improved in its process, since from the very first stages of its deployment it has already been presented in a well-developed form – precisely as a system. Therefore, it is not so much the subject of qualitative transformations as the continued improvement of the system integration tools already presented in it. The most important thing, however, is that the interpretation of these data from the point of view of the concept of systemogenesis clearly reveals the following important fact. In the professionalization process of personality in relation to

the dynamics of cognitive characteristics formation, one of the fundamental principles of systemogenesis is the principle of progressive *integration.*

Fifthly, during professionalization, the natural dynamics of the second main index – the differentiation of basic cognitive qualities – are revealed. It also increases, but which is also important, its dynamics is presented in a much more moderate form. Consequently, in relation to the professiogenetic dynamics of the general complex of cognitive qualities acting as PIQs, it can be said that there is another fundamental systemogenetic principle – the principle of increasing *differentiation.*

Sixth, the dynamics of the change in the SCI of the complex of the examined qualities are expressed much more than the degree of variability of the SDI values. Due to the superposition of these two dependencies, another, equally significant, pattern of this kind arises. This consists in the fact that with the increase in professionalization, the values of the most general structural index increase – the overall organization of the structure. At the same time, it is the most general indicator of the structural organization of any system (in this case, the complex of cognitive qualities as determinants of activity) that acts as the main indicator of the overall organization, the formation of the system as a whole. Thus, it shows how well the system itself is formed and how its main "components" are consolidated. Thus, in relation to the obtained results, the effect of another specific system-genetic pattern is clearly revealed – the *consolidation* principle.

Seventh, as is well known, the concept of system-genesis establishes other equally important principles — the "simultaneous establishment" of system components, "ensuring a sufficient effect" in its functioning, and target determination (Shadrikov, 1982). In this regard, it is very important and convincing that they are no less clearly evident in the profession-genetic dynamics of fundamental cognitive qualities. However, their action is more implicit and is not revealed by the empirical data obtained in this study, but also by the more general and well-known phenomena and patterns described both in cognitive psychology and in the psychology of professional activity. Therefore, in particular, the principle of the "simultaneous establishment" of system components is clearly obvious. Indeed, the very essence of the composition and content, as well as the overall organization of the cognitive subsystem of the psyche, which components are the qualities studied, lies in its being a formation of a specifically systemic type. But this means that all of its components—the fundamental cognitive qualities associated with both processes and operations—are already initially and, moreover, attributively represented, both synchronously and in an associated manner. During the acquisition of a professional activity, they are not so much formed as transformed and specified as already "established" that exists even before the activity is mastered. Their subsequent transformation takes place in accordance with the content of the activity to be mastered, as well as the combination of its requirements. This is even more important since the

basic content of the information activity is also highly cognitive in nature. The initially and "simultaneously established" components of the system (in this case, the cognitive subsystem of the psyche) and the most important attribute of information activity—its cognitive nature—are fundamentally congruent, which explicates the special importance of this principle in relation to this class of activities. Consequently, in relation to the professiogenesis of information-related activity, it is possible to fully justify the observation of the "*simultaneous establishment*" principle.

Furthermore, we can also ascertain the observance of the principle of "*ensuring a sufficient effect"*, which, as is well known, states that at any stage of system-genesis, each component of the emerging system is represented with a degree of development sufficient for its functioning as a whole. This is precisely one of the attributes of the cognitive subsystem of the psyche, since all of its components (processes and operations) at any level of development can objectively be represented within it only in a form sufficient for its functioning. Otherwise, that is, if even one cognitive process "fails" its functioning becomes objectively impossible. This, of course, is a consequence of another crucial regularity of cognitive organization, which is defined by the concept of "fully connected" cognitive processes (Anderson, 1985).

Finally, perhaps the most clear, the principle of goal *determination* is revealed, although in a specific form. The fact is that the main objective basis for distinguishing the important qualities of professional activity, as considered to be axiomatic in the theory of professional activity (Karpov, 2015), is a clearly functional criterion – its focus on ensuring a particular basic aspect of activity, as well as a particular function associated with its implementation. Consequently, this differentiation is carried out on the basis of the specific purpose for which these functions themselves are realized. In other words, each PIQ, including the cognitive qualities that serve as its functions, evolves as a kind of "functional organ" which ultimately aims to achieve a very specific goal.

Therefore, we can conclude that the profession-genetic dynamics of a complex of fundamental cognitive qualities as subjective determinants of information-related activity reveal all the most important system-genetic principles — inequality, heterochrony, progressive integration, increasing differentiation, sequential consolidation, simultaneous establishment, ensuring a sufficient effect, and goal determination. This is a very significant argument in favor of the fact that the very origin of the studied category of subjective determinants of activity – the fundamental cognitive qualities – is subject to the fundamental laws of systemogenesis – its principles – and therefore is systemogenesis itself. In addition, we point to another important circumstance: the increase in the SOI value, which indicates an increasing degree of structural consolidation, effectively means an increase in the overall degree of embodiment of the systemic form of organization within it. Therefore, the most general meaning of system genesis as a type of development

is that, during its course, the degree of realization of consistency as a form of organization in activities and its PIQs is consistently increasing. Therefore, system-genesis is not only the formation of a system, but also the formation of a *system* as a fundamental form of organization.

Eighth, in the final stage of interpreting the results, the matrices, which were determined based on the array of all the cognitive qualities examined and which characterize their structural organization in different experience groups, were compared using the $\chi 2$ test. This revealed the following facts. The matrices and, accordingly, the structures of cognitive qualities acting as PIQs, are qualitatively uniform – *homogeneous* – across all work experience groups. In other words, they differ not qualitatively, but only in terms of their degree of organization. This result, in our opinion, should be explained by taking into account the following defining circumstance. The fact is that all basic cognitive qualities, which form one of the basic categories of subjective determinants of activity as a whole and therefore act in relation to them as PIQs, are characterized simultaneously by another – more general, even attributive – characteristic. All of them, unlike other categories of the PIQs, are not so much *activity*-driven and therefore directly linked to the activity itself, but are determined by the *general organization* of the psyche as a whole and its procedural content in particular. In other words, their composition and content, structure and organization have a supra-activity, meta-activity character and determination. Consequently, this determination cannot and should not be transformed qualitatively "in response" into an activity-based determination (as in other categories of subjective determinants). On the contrary, their organization should be sufficiently tolerant of activity-based determination in terms of its structural characteristics. However, it can and, once again, must be sensitive to it in terms of the degree of structure itself, the degree of perfection and therefore effectiveness. This was exactly what was revealed in the overall results presented. They demonstrate that the structures of fundamental cognitive qualities remain invariant — homogeneous — at different stages of professionalization, but precisely in terms of their organization. However, they undergo significant transformations in the degree of this organization. Consequently, an important pattern in the professiogenetic dynamics of fundamental cognitive qualities is the prioritized development of their degree of organization — coherence, structure — which occurs in the context of maintaining the invariance of their character — the pattern of their organization. This also means that even such a powerful — actually activity-based — determination does not lead to fundamental transformations in the structure of cognitive qualities. The structural organization of the complex of fundamental cognitive qualities, which are PIQs of activity at different stages of its profession-genesis is fundamentally invariant in content and character — in terms of the general pattern — but equally variable in terms of the degree of organization. This is one of the main differences between the

profession-genesis of core cognitive qualities as determinants of information activity and all other categories previously studied (especially, professional skills, a number of individual-personal qualities, and metacognitive determinants).

Conclusion

To summarize the above analysis, the following key *conclusions* can be formulated.

First, during the professionalization of IT specialists (programmers), significant and consistent transformations occur in one of the most important categories of subjective determinants of activity—core cognitive qualities, which function as the PIQ in relation to it. Consequently, their entire complex forms an important, qualitatively specific dimension of the overall professional genetic dynamics as such, and its study can significantly contribute to discovering the patterns of this dynamics as a whole.

Secondly, this dynamic is characterized by all the fundamental patterns captured in the concept of the principles of systemogenesis—the principles of unevenness and heterochrony, progressive integration and increasing differentiation, consolidation, the "simultaneous establishment" of system components, and the "ensuring of a sufficient effect" in terms of its functioning and target determination.

Thirdly, the dynamics of the development of core cognitive qualities during professionalization is characterized by a combination of their transformations at two levels—analytical and structural. At the former, changes in the degree of expression, that is, the development of individual cognitive qualities, occur. At the latter, significant changes in the organization of their entirety occur. The structural organization of the complex of core cognitive qualities, which function as the PIQs of activity, at different stages of professiogenesis is fundamentally invariant in content and character—in terms of the general pattern—but, at the same time, equally variable in its level in terms of organization degree.

Fourth, the identified dynamics also exhibit more specific, but also significant, genetic patterns—the coordinated nature of the restructurings, their fundamentally nonlinear nature, the phenomenon of the sensitive period, etc.—which provides further considerable evidence of the complexity of their transformations.

Fifth, the dynamics of the transformation of core cognitive qualities as subjective determinants at different stages of professionalization is characterized by a combination of quantitative and qualitative (structural) transformations. The former manifest themselves in changes in the degree of severity—their level of development. The latter consist of significant differences in the degree of structural organization of these determinants at different stages. Furthermore, an important and specific feature of core cognitive qualities

is the prioritization of the degree of their structural organization, rather than the level of their development—the individual measure of severity.

Sixth, in the most general and fundamental sense, the entire complex of established patterns indicates that the process of programmers' professionalization is realized according to a systemogenetic principle, that is, it represents one of the manifestations of systemogenesis as such.

Seventh, in terms of methodology, the obtained data, as well as their interpretation, enable us to draw two more important conclusions. They provide new major arguments for extending the fundamental principles of the theory of activity systemogenesis to a new, previously unexplored class—the subject-informational class—which increases its generalizability. At the same time, the process of developing this activity during professionalization, considered in terms of one of the most important categories of its subjective determinants—fundamental cognitive qualities—receives a more profound explanation, since its subordination to the basic principles of systemogenesis and, consequently, its belonging specifically to the systemogenetic type of development, is explicated.

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Author Contribution

Anatolii Viktorovich Karpov provided academic guidance for the study, based on the application of the methodology of professional activity systemogenesis to the development of information-related activity issues; analyzed data, and contributed to theoretical generalization of research findings.

Anna Vadimovna Chemyakina developed the concept of the study using the methodology of metacognitivism, analyzed data, and interpreted the results.

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Conflict of Interest Information

The authors have no conflicts of interest to declare.