

The Interconnection of Metacognition and Executive Functions in Childhood: A Cultural-Historical Perspective[□]

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ABSTRACT

Objective. This review focuses on the interrelation of executive functions and metacognition as seen from a cultural-historical perspective.

Results. Based on research conducted over the past 15 years, we show these constructs' commonality and differences. Special attention is paid to the development of executive functions and metacognition, their connection with children's academic success, and the role of the social aspect in their development. The importance of an adult in the directed formation of metacognition and executive functions is demonstrated, which confirms the cultural-historical theory. Within the cultural-historical paradigm, several mechanisms for the development of executive functions are considered: 1) imitation based on understanding; 2) sign mediation; and 3) communication in a social situation of development. Vygotsky noted that higher mental functions originate on the basis of live interactions between people, which are then internalized and turned into psychological functions.

It is shown that the most common model of the structure of executive functions is one that includes such components as "working memory," "inhibitory control," and "cognitive flexibility."

Conclusion. Our analysis showed that Piaget's concepts have considerable influence on research of executive function development. But there is a certain difficulty in explaining emotional regulation within the context of metacognition from Piaget's standpoint. At the same time, Vygotsky asserted the unity of affect and intelligence, which suggests the existence of behavior control and, in particular, of emotional processes at the metacognitive processes level.

Keywords: Metacognition, executive functions, cultural-historical theory, metacognitive regulation

[□] This article is a modified version of a previous paper by Veraksa, A.N., Veraksa N.E. (2021). Vzaimosv'яз' metapoznaniia i reguliatorynykh funktsii v detstve: kul'turno-istoricheskii kontekst [Interconnection of metacognition and executive functions in childhood: cultural-historical context]. *Vestnik Moskovskogo Universiteta. Seriiia 14. Psikhologiiia* [Lomonosov Psychology Journal], 1, 79–113. <https://doi.org/10.11621/vsp.2021.01.04>

Highlights:

- Metacognition and executive functions are distinguished as separate constructs, but are similar constructs when metacognition is considered as a component of executive function.
- Metacognition and executive functions are associated with children's academic success, including in the development of mathematics skills, speech, and literacy.
- The key role in the development of metacognition, as well as of executive functions, belongs to the adult, who is the organizer of the interaction situation

АННОТАЦИЯ

Актуальность. Обзор посвящен взаимосвязи регуляторных функций и метапознания в контексте культурно-исторической перспективы.

Результаты. На материале проведенных за последние 15 лет исследований показана общность и различия указанных конструктов. Отдельное внимание уделяется развитию регуляторных функций и метапознания, их связи с академической успешностью детей, роль социального аспекта в их становлении. Показана значимость взрослого в направленном формировании метапознания и саморегуляции, что подтверждает положения культурно-исторической теории. В рамках культурно-исторической парадигмы рассматривается несколько механизмов развития регуляторных функций: подражание, основанное на понимании; знаковое опосредствование; а также общение в социальной ситуации развития. Л.С. Выготский отмечал, что высшие психические функции возникают на основе реальных взаимодействий людей, интериоризируются, превращаясь в психологические функции.

В обзоре установлено, что одной из распространенных моделей структуры регуляторных функций является модель, которая включает в себя такие компоненты как «рабочую память», «сдерживающий контроль» и «когнитивную гибкость».

Выводы. На основании проведенного анализа можно утверждать влияние концепции Ж.Пиаже на исследования развития регуляторных функций. Известную сложность вызывает объяснение эмоциональной регуляции в контексте проблем метапознания. Вместе с тем Л.С. Выготский говорил о единстве аффекта и интеллекта, что позволяет предположить существование управления поведением и в частности эмоциональными процессами на уровне метакогнитивных процессов.

Ключевые слова: Метапознание, регуляторные функции, культурно-историческая теория, метакогнитивная регуляция

Ключевые положения:

- Метапознание и регуляторные функции выделяются как отдельные конструкты и как схожие конструкты, когда метапознание выступает компонентом регуляторных функций
- Метапознание и регуляторные функции связаны с академической успешностью детей, включая развитие математических навыков, речевое развитие и грамотность
- В развитии метапознания и регуляторных функций ключевая роль принадлежит взрослому, который организует ситуацию взаимодействия

RESUMEN

Objetivo. La revisión se centra en la relación entre funciones reguladoras y metacognición en el contexto de una perspectiva histórico-cultural.

Resultados. Basado en investigaciones realizadas en los últimos 15 años, se demuestra la similitud y las diferencias entre estos dos constructos mencionados. Se presta espe-

cial atención al desarrollo de las funciones reguladoras y de la metacognición, su relación con el éxito académico de los niños y el papel del aspecto social en su formación. Se muestra la importancia del adulto en la formación dirigida de la metacognición y la autorregulación, lo que confirma los principios de la teoría histórico-cultural. Dentro del marco del paradigma histórico-cultural, se consideran varios mecanismos para el desarrollo de las funciones reguladoras: la imitación basada en la comprensión; la mediación de signos; y la comunicación en situaciones sociales de desarrollo. Vygotsky sostenía que las funciones mentales superiores se originan a partir de las interacciones reales entre las personas, se interiorizan y se convierten en funciones psicológicas.

En la revisión se establece que uno de los modelos comunes de la estructura de las funciones reguladoras es aquel que incluye componentes tales como “memoria de trabajo”, “control inhibitorio” y “flexibilidad cognitiva”.

Conclusiones. Basado en el análisis realizado, se puede afirmar que la concepción de Piaget ha influido en las investigaciones sobre el desarrollo de las funciones reguladoras. Se presenta una dificultad en explicar la regulación emocional en el contexto de los problemas de metacognición. Sin embargo, Vygotsky hablaba sobre la unidad entre afecto e inteligencia, lo que nos permite suponer la existencia de control de comportamiento y, específicamente, de procesos emocionales a nivel de procesos metacognitivos.

Palabras clave: Metacognición, funciones reguladoras, teoría histórico-cultural, regulación metacognitiva

Destacados:

- La metacognición y las funciones reguladoras son identificadas como constructos independientes y también como constructos similares, cuando la metacognición se encuentra como componente de las funciones reguladoras.
- La metacognición y las funciones reguladoras están relacionadas con el éxito académico de los niños, incluyendo el desarrollo de habilidades matemáticas, el desarrollo del lenguaje y la alfabetización.
- En el desarrollo de la metacognición y las funciones reguladoras, el adulto desempeña un papel clave al organizar la situación de interacción.

RESUME

Objectif: cette revue porte sur la relation entre fonctions régulatrices et métacognition dans le contexte de la perspective historique-culturelle.

Résultats. Sur la base des données d'études réalisées au cours de 15 dernières années les traits communs et les différences des constructions conceptionnelle sont démontrés. Une attention particulière est portée sur le développement des fonctions régulatrices et de la métacognition, sur leur liaison avec le progrès scolaire des enfants, sur le rôle d'aspect social dans leur formation. L'importance d'un adulte dans la formation dirigée de la métacognition et de l'autorégulation est démontrée, ce qui confirme les dispositions de la théorie historique-culturelle. Dans le cadre du paradigme historique-culturel, plusieurs mécanismes de développement des fonctions de régulation sont envisagés: l'imitation basée sur la compréhension; signer la médiation; ainsi que la communication dans une situation de développement social. Vygotski a noté que les fonctions mentales supérieures naissent sur la base d'interactions réelles entre les personnes, sont intériorisées et se transforment en fonctions psychologiques.

Cette revue a révélé que l'un des modèles courant de structure des fonctions régulatrices est le modèle qui inclut tel composant que «la mémoire de travail», «contrôle inhibiteur» et la «flexibilité cognitive».

Conclusions. D'après cette analyse effectuée on peut constater l'influence de la conception de Piaget sur les recherches du développement des fonction régulatrices. Il y a une certaine difficulté à expliquer la régulation émotionnelle dans le contexte de problèmes

de métacognition. Pourtant Vygotski a parlé de l'unité de l'affect et de l'intelligence, ce qui suggère l'existence d'un contrôle du comportement et, en particulier, des processus émotionnels au niveau des processus métacognitifs.

Mots-clés: Métacognition, fonctions régulatrices, théorie historico-culturelle, régulation métacognitive

Points principaux:

- La métacognition et les fonctions régulatrices se distinguent comme des constructions distinctes et comme des constructions similaires lorsque la métacognition est un composant des fonctions régulatrices.
- La métacognition et les fonctions régulatrices sont liées au progrès scolaire des enfants, y compris le développement des compétences en mathématiques, le développement du langage et l'alphabétisation.
- Dans le développement des fonctions métacognitives et régulatrices, le rôle clé est joué par l'adulte qui organise la situation d'interaction

Introduction

Metacognition is a cognitive psychology subdiscipline devoted to studying how people control their mental activity and use their assessments to determine subsequent cognitive or behavioral responses. Piaget, one of the founders of cognitive psychology, suggested that awareness of one's thoughts is an aspect of cognitive development that appears around the age of seven.

In 1971, Flavell introduced the "metamemory" concept and related it to developmental psychology (Flavell, 1971). His laboratory studies have shown that children can improve their memorization performance if researchers help them think about tasks and possible strategies for solving them. Later in 1979, Flavell introduced the "metacognition" concept as a construct that suggests the interrelation between metacognitive knowledge, metacognitive experience, and metacognitive actions or skills. In 1985, Flavell defined metacognition as "cognition about cognition."

Two components of metacognition were identified: 1) declarative metacognitive knowledge (knowledge about cognition, learning processes, memory work, etc.); and 2) procedural metacognition, whose metacognitive skills include: metacognitive monitoring (the subjective assessment of cognitive processes) and metacognitive control (regulation of current cognitive activity, selection of material for study, time determination, etc.).

Developmental psychology research shows that, like adults, children base their metacognitive judgments on heuristic cues (e.g., ease of remembering, degree of familiarity with the material, etc.), although the magnitude of their dependence on such cues may increase with age (Koriat & Ackerman, 2010; Lockl & Schneider, 2002). Therefore, metacognitive judgments are characterized as "gut feelings" (Price & Norman, 2008) that originate from subjective features of decision-making experience. Metacognitive actions play a key role in metacognitive processes. Metacognitive actions are high-level actions which involve the regulation of one's own cognition and behavior. They consist of such components as planning, monitoring, and reflection regarding the action being performed.

The concept of regulatory or executive functions emerged 10 years later within clinical child psychology and neurophysiology. Executive functions have been studied primarily in samples of children and adults experiencing brain disorders (Welsh & Pennington, 1988). Executive functions research in children relies on the most validated three-factor model by Miyake (Miyake et al., 2000), which identifies working memory, inhibitory control, and cognitive flexibility as their main components. However, some researchers argue that for preschool children, it is legitimate to talk about only one general factor (see, for example, Lee, Bull, & Ho, 2013; Wiebe, Espy, & Charak, 2008), while others mention the validity of a three-factor model use (Lehto et al., 2003; Veraksa et al., 2020). The work by Lee and his colleagues, using materials from tracking the executive functions development of children age 5 to 15 years, demonstrates that if for children under 13 years old the most appropriate model consists of two factors, then at an older age, these factors become three (Lee et al., 2013). It should be noted that such difficulties in unambiguously determining the structure of executive functions depending on age are usually explained by the specifics of the tasks used, in which at least two regulation components can be simultaneously involved.

The problem of regulation was posed within the cultural-historical paradigm. In discussing the development of voluntary behavior, Vygotsky turned to three concepts, which he combined thus: “*the concept of higher mental function, the concept of cultural development of behavior, and the concept of mastering one’s own behavioral processes*” (Vygotsky, 1983, p. 14).

Vygotsky began his analysis of the problematics of voluntary regulation by looking at imitation. He defined imitation as reproducing the action of another on the basis of understanding, which includes the idea of the action’s purpose and of the motivation driving the other person. The child not only reflects the motive, but also realizes why this motive determines the behavior of another. Understanding also includes awareness of the actions’ operational side as well as control over one’s own actions, which must correspond to the imitated behavior. Thus, according to Vygotsky, imitative action must be reflexive, *i.e.*, rely on metacognitive processes.

In speaking about the development of higher mental functions, Vygotsky highlighted that regulation first originates on the basis of communication between people (an external form), and then turns inward (an internal form): “In general, we could say that the relationships between higher mental functions were once real relationships between people” (Vygotsky, 1983, p. 142). He associated the development of voluntariness with the use of artificial stimuli, in particular, signs. He wrote: “... we raise the question of the means by which behavior is mastered. Thus, *mastery of behavior is a mediated process* that is always carried out via known auxiliary stimuli...” (Vygotsky, 1983, p. 120). A sign functioning as an artificial stimulus, first acts as a means of communication, and then becomes a means of influencing a personality.

A striking example of the metacognitive regulation of memorization (or memory mastering), according to Vygotsky, is presented in the following passage: “... in the process of adaptation, the child remembers and follows various instructions, that is, he/she performs a number of mental operations. By performing them, the child accumulates and acquires a certain naive psychological experience, he/she begins to under-

stand how to remember, what memorization consists of, and when he/she understands this, he/she begins to correctly use this or that sign” (Vygotsky, 1983, pp. 158–159).

Vygotsky pointed out that this process develops by stages. The entire process of mastering cultural behavior proceeds as follows: “In the natural, or primitive, stage, the child solves the task directly. After solving the simplest tasks, the child moves on to the stage of using signs without knowing the method of their action. Then comes the stage of using external signs and, finally, the stage of internal signs” (Vygotsky, 1983, p. 161).

Thus, Vygotsky created his own approach to understanding the development of regulation; that approach is associated with the process of mastering the highest form of behavior. This process goes through four stages, which use imitation with understanding and cultural mediation through symbolic means. Although Vygotsky presents the staged nature of regulation’s development, this process can occur unevenly and fragmentarily, allowing the manifestation of similar phenomena at different ages, depending on the situation which requires appropriate regulation. In real practice, the manifestation of such tendencies can result in contradictory data on the age limits of metacognitive processes.

It should be noted that Vygotsky did not use the term “metacognition.” However, he studied similar key properties of higher mental functions, which include awareness and voluntariness. If this assumption is correct — *i.e.*, metacognition is included as a component of the structure of higher mental functions, ensuring awareness and voluntariness — then the development of metacognition and behavior regulation should depend on the type of means used by preschoolers, as well as the stage at which the children are mastering cultural behavior.

Development in Ontogenesis

The development of executive functions can be seen as early as the second year of life, when the child makes a successful choice between two stimuli and demonstrates the presence of working memory and inhibitory control; for example, when performing the children’s version of the Stroop test (Diamond, 2006). In ontogeny, inhibitory control — which manifests itself in increasing attention capacity — appears in the first year of life, reaching a significant development level by the age of 7 years (Jurado, & Rosselli, 2007). Vygotsky, in fact, considered the regulatory mechanism of inhibitory control as a higher mental function. He wrote: “It is extremely difficult for a child to inhibit the first decision that comes to mind and it is easier for him/her to give the most absurd answer than to admit his/her ignorance. Inhibition of one’s immediate reactions, the ability to delay a response in time is a product of development and education, which arises only very late” (Vygotsky, & Luria, 1993, p. 143). The switching development happens later, by 4 years of age, as evidenced by numerous studies using the card-sorting technique (Zelazo et al., 2003). At the same time, significant shifts in the development of all the components of executive functions are observed by the end of preschool age.

Traditionally, metacognition development has been thought to occur when children go to school. The vast majority of metacognition research has been con-

ducted on school students within the framework of educational psychology (Garcia et al., 2016). However, a number of studies have revealed that the ability to control cognitive operations manifests itself at a preschool age. Systematic observations of 3- to 5-year-old children indicate that they demonstrate metacognitive regulation in situations of joint interaction with peers, monitoring peers' activities, or independent activities on an ongoing basis (Whitebread et al., 2007). During this period, children, for example, talk about mental rotation in figurative terms when describing how they solve certain problems (Estes, 1998). That said, it is not until elementary school that children become adept at describing the content of their thoughts in a stream of consciousness manner (Flavell et al., 1995, 2000). In the same way, if at 4–5 years old children have inadequate ideas about their mnemonic capabilities, claiming that they will remember all the pictures presented to them, then at 6 years old they begin to realize the limitations of their own memory, and at 10–11 years old they understand that recognition is easier than memorization (Jaswal, & Dodson, 2009).

This vision of metacognition development is explained by adherence to Piaget's theory, within which awareness of the process requires the presence of a certain level of operational development. However, relatively recent studies show that, by analogy with the development of the theory of mind, we can also talk about the emergence of metacognition at a much earlier age. Thus, it has been demonstrated that already at the age of three, when solving a false belief task with an object's location change, children may verbalize an erroneous decision, but an analysis of their oculomotor activity suggests the presence of implicitly correct knowledge (Ruffman et al., 2001). Similarly, children demonstrate both procedural and declarative metacognition components at 3–5 years of age (see Marulis & Nelson, 2020). Moreover, monitoring skills develop before control skills (Bryce, & Whitebread, 2012).

The behavior of 5-year-old children can be seen as demonstrating elementary forms of orientation, planning, and reflection (Whitebread, 1999). A number of researchers argue that already at 2 years old, children are able to demonstrate metacognitive awareness, despite the limitations of their verbal reporting; the only problem is the use of adequate research methods (see Hembacher, & Ghetti, 2004; Lyons, & Ghetti, 2011).

A classic method for metacognitive monitoring research is to ask subjects about their cognitive processes before, during, and after completing a task. Testees are asked how well they have mastered certain information (learning judgments), and how confident they are in a given answer when completing the test (confidence judgments). In this respect, the metacognitive control level is measured by assessing changes in the participant's behavior based on monitoring data. For example, learning judgments are studied in conjunction with the time a testee spends learning certain information: the results of metacognitive monitoring are assumed to influence the increase in time needed for more complex information. Similarly, when they express a high confidence level, testees are expected to respond quickly, and in a situation with low confidence, they are expected to take longer to respond.

It is important to note that, despite children's ability to reproduce metacognitive skills — for example, assessing their own future success or the success of an already

completed task — preschoolers tend to inflate their own expectations, demonstrating wishful thinking; this corresponds to the understanding of intellectual development presented in the works by Piaget (Salles et al., 2016). At the same time, some studies have revealed that as early as 3 years old, children believe that they will have more difficulty remembering more complex stimuli than simple ones (Lipowski et al., 2013). The work by Destan and colleagues (Destan et al., 2014) showed that at 5-7 years old, children demonstrate effective metacognitive monitoring, as they correlate their own memorization abilities and the complexity of the stimuli. That being said, recording the time that children spent on memorization showed that only starting from the age of 6 was there a tendency to spend more time on material that was rated as more complex. However, the study by Destan and Roebbers (Destan, & Roebbers, 2014) showed a connection between the preschoolers' overestimation of the results of their mnemonic activity, and a lower level of metacognitive monitoring and control. This was not observed in children who underestimated their results. It was the latter who demonstrated a higher mnemonic activity development level.

In general, the research shows: 1) the validity of understanding the development of voluntariness as an uneven process; 2) that at a preschool age, children have the necessary monitoring level, but do not use it to control their behavior; and that 3) the ontogenesis of metacognitive skills depends not only on the characteristics of the means that the child begins to master, but also on the nature of the situation in which they are used.

Association with the Development of Mathematical Skills and Speech

Both executive functions and metacognition are associated with children's academic success in school.

Numerous studies have demonstrated the association of executive functions with speech development. Research by Welsh and her colleagues (Welsh et al., 2010) aimed at studying the development of executive functions and specific skills (such as literacy and the ability to think quantitatively); 164 children 4- to 6-years-old took part. The study lasted over three stages: at the beginning of the kindergarten's middle group, at the end of the kindergarten's middle group, and at the end of the kindergarten's senior group. The results indicated that the development of such components of executive functions as working memory and attention control happens simultaneously with the development of such specific skills as literacy and the ability to think quantitatively. In addition, it turned out that the development of the executive functions mentioned above during the children's education while in the kindergarten's middle group directly affects the children's ability to successfully solve reading and mathematics tasks in the kindergarten's senior group.

In studies of the interrelation of speech and executive development in senior preschool children (5-6 years old), it was discovered that with a high level of executive function development, the child's speech will be more correct lexically and grammatically (Veraksa et al., 2018). It has also been found that a child's ability to produce narratives with the correct macrostructure (that is, meaningful, with the correct logic and structure of the narrative) is associated with his/her working memory and cogni-

tive flexibility (Veraksa et al., 2019). Based on these results, we can conclude that the development of speech skills at a preschool age is to a greater extent associated with auditory working memory and cognitive flexibility, and to a lesser extent with inhibition and visual working memory.

A number of studies show the interrelation of executive functions and mathematical skills development (see, for example, Welsh et al., 2010), to which working memory makes a greater contribution in preschool age (Blair & Razza, 2007; Bull & Scerif, 2001).

Metacognition level is also correlated with children's success in mathematics and reading (see, for example, Bryce et al., 2015). There is evidence that it is primarily procedural metacognition that is associated with children's success in task-solving (Dunlosky & Rawson, 2012; Geurten, Catale, & Meulemans, 2015). Children who are able to notice their errors when performing arithmetic operations (activity's metacognitive monitoring) are better able to perform them (Bellon et al., 2019).

There are a limited number of studies that simultaneously link both executive functions and metacognition to academic success. The research by Roebbers and colleagues (Roebbers et al., 2012) involved 209 children of 7 years old, who were assessed in terms of executive functions development and metacognition at this age and one year later. The results were compared with children's performance in mathematics and literacy, and showed an association with both executive functions and metacognition. In a similar way, the work by Lai and colleagues (Lai et al., 2019) on a sample of more than 400 children of 9-14 years old showed a connection between children's executive functions and metacognitive monitoring and their success in literacy and arithmetic.

In a study by Rodriguez and colleagues (Rodriguez et al., 2018), based on assessments of children's success in mathematics, speech development, art, and regulation development (measured using the BRIEF questionnaire completed by parents), an association was discovered between 6- to 9-year-old children's academic success, and all regulation components and metacognitive monitoring. In a longitudinal study by Blankson (Blankson et al., 2017), it was found that the level of executive functions and metacognitive skills development at 3-4 years old is predictive of mastering mathematics, reading, and social skills at the age of 5 years.

The results obtained are consistent with Vygotsky's cultural-historical theory, within which regulation and metacognitive processes are parts of a single mechanism for controlling behavior associated specifically with the process of mastering higher mental functions. Therefore, it is expected that there will be an association between the academic achievement and the development of both executive functions and metacognitive processes.

Comparison of the Development of Executive Functions and Metacognition

Let us turn to studies that examine the connection between the development of executive functions and metacognition. In these studies, two tendencies can be detected: one is aimed at establishing differences in development, and the other at identifying their similarities. For example, data obtained in a study by Garcia et al. (2016) showed that children with higher executive function development also have higher

metacognition levels. Most of these studies are of a confirmatory nature. They use correlations, which, unfortunately, do not allow determining the direction of the connection. Latent variables relevant to the study of such mutual influence are, as a rule, not considered (for example, the educational program based on which children are trained, characteristics of family upbringing, etc.).

The work by Bryce and colleagues (Bryce et al., 2015) revealed that in 5-7-year-old children, there is a connection between monitoring and inhibitory control. Poor development of metacognitive skills correlated with poor development of working memory and inhibitory control. At the same time, these patterns turned out to be more pronounced in younger children. This fact, according to the study's authors, suggests that in order to develop metacognition, it is necessary to first achieve a certain level of executive functions development. In other words, the primacy of regulation in relation to metacognition is affirmed, and, accordingly, the development of these processes is not identical.

Certain difficulties in analyzing the differences between executive functions and metacognition are introduced by the fact that a number of authors include metacognition as part of executive functions (Dawson, & Guare, 2010; Isquith et al., 2004). This speaks in favor of Vygotsky's approach, in which metacognition, as already noted, is included in the structure of higher mental functions.

Among longitudinal studies, we were able to find few studies in which the development of executive functions' main components and the control aspect of metacognition skills (a child's understanding of the complexity of spelling words) were tracked; this occurred, for example, over a period of one year in 119 children of 8 years old (Spiess et al., 2016). The results indicated that there was no interrelation of the development of executive functions during the first measurement, and the metacognition development level in the second measurement.

If we proceed from the idea that the development of regulation is primary, then the conclusions of researchers on executive functions seem quite logical: *i.e.*, that improvement in self-control is due to age and experience, the children's increased ability to process information at lower consciousness levels, and an increase in psychological distance, which allows children to flexibly choose their responses, and not be limited by the reaction-stimulus models.

From the metacognition perspective, self-regulation develops due to the awareness of one's own cognitive activity and the acquisition of control over one's thoughts and actions. The commonality between the development of executive functions and metacognition has various explanations. One of them is substantiated by the laws of intellectual development and, in particular, by the development of intelligence in stages, as described by Piaget, as well as by indications of the development's dependence on the formation of representations (Demetrio, & Spanoudis, 2017). Most works analyzing the interrelation of executive functions and metacognition are limited to theoretical analysis of the constructs, since empirical research results are quite contradictory (Roebbers, 2017). The dependence of the development of regulation and metacognition on the characteristics of representations indicates the connection of these processes with mediation systems, since the form of representation depends on the means used by the child to solve a particular task. This confirms the adequacy

of considering executive and metacognitive processes within the cultural-historical theory as components of higher mental functions.

One of the factors influencing the results of studying the connection between executive functions and metacognition in children is the use of the same survey methods that are used with adults. The data obtained are subjective and correspond poorly to the results obtained using neuropsychological and other research tools. Toplak et al.'s systematic analysis of studies that used observational and survey methods compared with standardized procedures, showed a very low correspondence level, revealing correlations in only 24% of the studies (Toplak et al., 2013). It is obvious that if survey methods characterize adults' ideas about children's behavior rather than the children's behavior itself, then individual evaluation methods offer children "optimal" opportunities to demonstrate the development of executive functions. Comprehensive assessment of executive functions, as a rule, involves a combination of these methods, which, with rare exceptions, is not found in the conducted studies.

Thus, despite the apparent structural commonality of executive functions and metacognition, there are a number of obvious differences. For example, the division of executive functions into hot and cold ones has no analog in relation to metacognition.

One of the constructs for understanding the interrelation of executive functions and metacognition is the cognitive self-regulation model, which is based on the intersection of these concepts. One might expect the intersection to occur along the lines of monitoring both executive functions and metacognitive processes. However, studies indicate that there is a specific connection between executive functions with metacognitive control, but not with metacognitive monitoring.

Sergeenko introduces a new concept of "behavior control," which is considered the primary basis of regulation, different from subjective regulation and not reducible to the concept of self-regulation or regulation of mental states. The term "behavior control" emphasizes the psychological level in the organization of regulation (Sergeenko, & Zhuravlev, 2018).

There are significant data on which the criticism of the construct of executive functions is based. Ardilla talks about the possibility of distinguishing metacognitive executive functions from emotional executive functions (*i.e.*, "cold" and "hot" executive functions), emphasizing the connection of metacognitive skills with a situation that does not require a high level of inhibitory control activation (Ardilla, 2013). At the same time, other researchers, in analyzing the differences between "hot" and "cold" functions, highlight the impossibility of isolating the children's emotional involvement under laboratory conditions (Doebel, & Munakata, 2018); that is, the division of executive functions should be carried out according to the degree of emotionality of the child performing the task, his or her specific motivation.

Following the cultural-historical paradigm allows us to talk about the unity of executive functions and metacognition. Vygotsky spoke about the unity of affect and intellect. In this case, metacognitive processes should, in principle, allow for the presence of an emotional component.

Some researchers have suggested that the development of executive functions happens as a result of the accumulation of knowledge, beliefs, and values that sup-

port their use in relation to certain goals, which are often determined by culture (see Doebel, 2020). So, for example, the fact that some children cope more successfully with the card-sorting task may be explained by the fact that these children have had richer experience in identifying the basis for categorization in the perception process (color, shape), while other children did not have such experience. Therefore, in fact, the authors are studying how children get control over their own behavior, which allows us to consider this study in the context of Vygotsky's approach. As mentioned above, Vygotsky called the second stage the naive psychology stage. At this stage, the connection between means and action is external.

It should be noted that Flavell considered metacognitive experience (thoughts and feelings that a person experiences during cognitive activity) as the basis for control at the conscious level. Therefore, executive function development should be carried out not so much in a laboratory context, but with the involvement of values instilled in the child (for example, transferring the value of self-control through stories, patterning, etc.). Based on memory research, Causey and Bjorklund demonstrated that already at the age of 3, children tend to perform a memorization task in a situation of personal gain, but won't do it when asked by an adult in a situation of no gain (Causey, & Bjorklund, 2014).

Studies on metacognition have also noted the limited transfer of learned strategies. This term is called the "unification deficit," which is often determined by the distinction between knowledge and the application of a particular metacognition strategy. Often, authors similarly resort to explaining the difficulties of transference by motivational and personality factors (Clerc et al., 2014).

The problem of motivation also arises in connection with the above-described phenomenon of children's high confidence in their own answers, which is interpreted as insufficiently developed metacognitive monitoring, leading to correspondingly weak metacognitive control. Thus, it has been discovered that high confidence is a condition for children to engage in sufficiently complex tasks, participation in which promotes development, despite errors (Shin et al., 2007). It is no coincidence that the issue of metacognition has recently become associated with issues of monitoring emotions and motivation (Efklides, 2011; Boekaerts, 1999). In analyzing the association with motivation, the authors mention it as a condition for metacognition, traditionally studied in the context of its stability. In a sample of 3-to-5-year-old children (Marulis, & Nelson, 2020), it was shown that motivation is associated with metacognitive skills, but not metacognitive knowledge.

Interestingly, emotional control at preschool age is associated with both inhibitory control and cognitive flexibility, which, according to the study's authors, indicates the representation of these tasks in various components of executive functions due to their particular significance (Isquith et al., 2004).

Social Aspect

Studies conducted on English- and Spanish-speaking samples indicate that the development of executive functions is significantly influenced by the socioeconomic status of the child (see, for example, Ardilla et al., 2005; Farah et al., 2006). First

of all, it is the parents' education level; this level mediates language development, which is directly related to the means of mastering of self-regulation. More educated mothers provide richer language patterns to their children and read more with their children compared to less educated mothers. In addition, low socioeconomic status implies limited opportunities for cognitive stimulation and relatively high stress levels. A study by Ardilla (Ardilla et al., 2005) found that it was the parents' education level, and not the type of educational institution (private or public), that was a stronger predictor of the development level of all components of executive functions.

Parenting style is no less important. Thus, in a sample of more than 600 families, it was shown that the parents' responsiveness to 2-year-old children predicts the children's executive functions development at 3 years old (Towe-Goodman et al., 2014). In a study by Lucassen and colleagues (Lucassen et al., 2015), also on a sample of more than 600 children, parenting styles and their association with the development of executive functions were evaluated in children of 3-4 years old. It turned out that in addition to low responsiveness levels in mothers, high levels of harsh parenting on the part of fathers were negatively associated with the development of executive functions in the children.

Typically, these findings are interpreted in terms of the lower stress levels experienced by children in a more stable environment, which allows them to practice self-regulation skills. However, the opposite explanation is also possible, according to which children with more developed executive functions evoke more positive responses from their parents.

If we follow Vygotsky's ideas, then any higher mental function initially arises as a social interaction between a child and an adult, and only then, in the process of its development, is it transformed into a sign and becomes an internalized higher mental function. Therefore, of course, the social aspects of interaction and communication between a child and an adult are decisive in the development of behavioral regulation (see, for example, Veraksa et al., 2020). Moreover, the cultural-historical paradigm appears to be a powerful tool for analyzing the development of regulation in younger children.

Opportunities for Directed Development

Various studies have demonstrated the effectiveness of using different types of influence to form executive functions. The well-known cognitive training system CogMed (Thorell et al., 2009) has been shown to be effective for developing working memory. One of the problems that arises when designing this type of research is the similarity of the content of the formative classes with the content of the measurement materials. For example, the work by Rothlisberger and colleagues (Rothlisberger et al., 2011) revealed the effectiveness of combining a group version of formative classes with individual ones, as well as with work in mini-groups for the development of all three components of executive functions in 5-7-year-old children. Yet the analysis highlights a high similarity level between the forms of children's activity proposed by the educational program and the techniques aimed at measuring these regulation

components. A meta-analysis of studies examining the effects of working memory training on academic success and achievement in mathematics, reading, and speech did not provide convincing support for this interrelation (see Redick et al., 2015). It is important to mention that long-lasting (in terms of implementation) programs for the development of executive functions also require quite a long period of teacher training, and the program itself requires children to have certain initial self-regulation skills as a condition for successful learning.

Role-playing allows the development of all components of executive functions. Moreover, both short-term (Veraksa et al., 2019) as well as long-term use of this technique in the educational process (Walker et al., 2020; Bodrova, & Leong, 1996) is effective. The results indicate, rather, the unity of executive and metacognitive processes within the theory of the development of higher mental functions. Vygotsky and his followers noted that executive functions are formed precisely in play activity due to the simultaneous retention of real and imaginary plans (Kravtsov, & Kravtsova, 2019; Smirnova et al., 2018).

In the study by Traverso and colleagues (Traverso et al., 2015), during 12 meetings conducted in a playful way, 5-year-old children performed tasks which were integrated by a plot and a role. It turned out that all the components of executive functions showed significant development, taking into account the fact that the tasks performed by children were not similar to test procedures. However, progress was observed only in hot, but not cold, executive functions.

Training inhibitory control development is quite a difficult task. It is no coincidence that there are certain studies in which the development of executive functions is carried out through the use of metacognitive monitoring and control. Thus, Kloo and Perner talk about the productivity of reflective task performance (Kloo, & Perner, 2003). Throughout the series of lessons, children were taught to repeat the rules while completing a card-sorting test. Specifically, the children were taught: a) to understand the correct dimension: “This is incorrect. We no longer play the game of color, the game of “yellow” and “green”. Now we are playing with shapes — a game with an apple and a house”; b) to consider the conditions: “In the game of shape, when you see an apple...” and c) to determine the consequences associated with each previous stimulus: “... now you need to point to the apple.”

Similarly, in research by Espinet and colleagues (Espinete et al., 2013), in case of an error, the child was asked to name the correct game and parameter, give an example, and perform the task again. The results revealed that with such training, children completed tasks more successfully. A study by van Bers (2014) also showed that already in children’s fourth year of life, reflective feedback is an effective technique for a significant shift in the performance of a switching task and the formation of a time-stable result. In another study (Rossignoli-Palomeque et al., 2019), metacognitive monitoring and control were presented more clearly and were included in a formative program of executive functions, during which children were taught to repeat instructions, verbalize a task (visible on the screen), and reinforce their own behavior in case of performing the task correctly (by gesture or word). The combination of training and metacognitive skills, according to the authors, led to a significant increase in executive function development in 6-8-year-old children.

As mentioned at the beginning of the article, Vygotsky emphasized that the foundation for the development of higher mental functions is understanding and mediation. In the studies of the preschoolers' regulation development discussed above, understanding played the role of reflection, and the instructions that the child mastered became a means of mastering his/her own behavior. In addition, it is necessary to take into account the fact that the adult created the zone of proximal development in these studies and he/she acted as the bearer of the highest or ideal form. All this allows us to consider mediation, as well as mastering one's own behavior through "conscious imitation," as essential moments in the formation of executive functions.

Of interest is the use metacognitive skills to develop hot executive functions. The research paradigm of delayed reward (when a child is asked, for example, to wait and not eat a treat at the moment in order to then receive twice as much) seems to be the most effective for analyzing the development of hot executive functions. In a study by Murray and colleagues (Murray et al., 2015), an attempt was made to form hot executive functions through directed attention training in 5-7-year-old children. The authors assumed that the child's difficulty in completing the task is due to the fact that he/she did not have enough skills to distract himself/herself from the treat and not think about or concentrate on it. During a special program, children received instructions on how to switch attention to various stimuli, and as a result, children from the experimental group completed the task significantly better.

Let us take a closer look at the research of Moriguchi and colleagues (Moriguchi et al, 2015), in which 3-5-year-old children performed a card-sorting task in two versions: one group, after completing it, received repeated instructions from an adult, and the second group explained the instructions to a doll. It turned out that in the second group the results improved significantly.

The studies described above show the importance of metacognitive monitoring for effective learning (Destan & Roebbers, 2014), which can be used by educators as a strategy to develop children's ability to learn. A study by Simons and colleagues (Simons et al., 2020) discovered a connection between the level of metacognition development (understanding of the successful learning key factors) and voluntary memorization of material by children in grades 1-6. The authors emphasize that the results indicate the significance of discussing metacognitive components within school education, since this can lead to an increase in the effectiveness of the learning process. In the reviewed studies, teachers actually developed reflection in children in exactly the same way, which allowed them to better understand the higher mental functions that were developing in them. This indicates the promise of applying the cultural-historical paradigm to the processes of executive functions formation and development in childhood.

We can fully attribute this same conclusion to the studies presented below, which use feedback as one of the traditional strategies for the development of metacognitive monitoring and control. For example, in a memory study of preschool children (van Loon et al., 2017), in a situation where children received information about the results of a task (after making their prediction about their confidence in their own answers), they used the information they received to correct their monitoring and achieve more

accurate error recognition. At the same time, in general, the children maintained a tendency towards a more optimistic assessment of their results.

In another study (van Loon, & Roebels, 2020), 5-7-year-old preschoolers were divided into three groups when performing a memorization task and problem solving by analogy: those who received feedback regarding the result (correct or incorrect answer); those who received feedback regarding the result and the child's prediction (your answer was correct, and you correctly rated it as correct; your answer was correct, but you incorrectly rated it as incorrect, etc.); and those who did not receive feedback. The results convincingly demonstrated that children who were receiving feedback adjusted their metacognitive monitoring and, over the course of the experiment, improved the level of concurrence between the correctness of answers and children's prediction (correct answer and assessing it as correct or incorrect and assessing it as incorrect).

Although there are a large number of studies that show possible means of developing executive functions, very few are related to the children's subsequent behavior outside of laboratory conditions. In the work by Volckaert and Noel (Volckaert, & Noel, 2016), the directed formation of the executive functions, as the authors mention, was carried out through the development of executive functions' metacognitive component. One of the program's features was the use of heroes — representatives of various professions, each of which represented an executive function. For example, a police officer blows his whistle and makes a "stop" hand signal, which metaphorically represents inhibitory control. The children also learned the hero's song "Stop: first I think, and then I do." Just like other heroes - the statue and the detective — the police officer helped the children to remain calm and look for mistakes. By completing the task correctly (coping with, for example, the policeman's task and holding back their answer), the children received police cards; when they were making mistakes, the children lost their cards. In total, the program included 16 lessons of 45 minutes each.

The results demonstrated not only the development of executive functions, but also a decrease in problematic behavior in children, according to a survey of their parents and teachers. This study also shows the productivity of the cultural-historical theory of development in the formation of higher forms of behavior. As can be seen from this study's design, the formation of executive abilities was built in accordance with the Vygotsky's perspective: external forms of behavior control were transformed into internal ones. This transformation was carried out strictly in adherence to the law of development of higher mental functions formulated by Vygotsky.

Among the large number of studies aimed at executive function development, some have obtained results indicating the complexity of metacognition development. Thus, in the work of Andersen and colleagues (Andersen et al., 2019), 66 children underwent a program dedicated to art and culture, which included 36 different types of activities aimed at mastering the arts (dance, music, theater, visual art, etc.) for 12 weeks. A teachers' survey revealed that, as a result of the intervention, significant changes were observed in the components of the children's executive functions, but not in the metacognition indicator. It seems from the perspective of cultural-historical theory that this study would be more effective from the point of

view of the formation of metacognitive processes if the authors identified the means that make it possible to control higher forms of behavior, including metacognitive functions, and included these means in the experimental program. This remark can be applied to most studies aimed at developing mechanisms for regulating children's behavior.

In the research by Flook and colleagues (Flook et al., 2010), an attempt was made to form executive functions and metacognition via a short-term program (8 hours long) for 7-9-year-old children. The program focused children on their own sensory feelings, the position of their bodies in relation to other people, and relationships between people. The program combined physical activity, the work of directed imagination with group performance of tasks related to the attention development, the ability to take the position of another, imagining the interrelation of processes, etc. The use of such a short-term program has shown its effectiveness based on the results of the BRIEF questionnaire filled in by teachers and parents of children from the experimental and control groups.

This study, just like the works presented above, very clearly demonstrates the role of reflection in the development of regulation and metacognition; in addition, it also highlighted the importance of children's joint interaction when solving group problems.

Results

1. An analysis of the works discussed convincingly shows that preschool age is an extremely important period in the development of executive functions and metacognition.
2. Metacognition and executive functions are associated with children's academic success, including the development of mathematics skills, speech, and literacy.
3. In research on the association of metacognition and executive functions, two trends can be traced: one is aimed at establishing differences in their development, and the other is aimed at identifying their commonality. The coherence of metacognition and executive functions development is explained in different ways: by the stages of intellectual development and the peculiarities of the development of representations. Similarities and differences are influenced by the parents' responsiveness, their educational level, and other factors.
4. A number of studies have indicated the possibility of direct influence on the development of executive functions through the use of reflection and learning through play.
5. Particular attention should be paid to the adult's role in the formation of metacognition and executive functions. In some studies, adults not only intensified the processes of children's awareness of executive mechanisms, but the adult himself/herself created a certain developmental situation, characterized by the presence of the zone of proximal development. Moreover, the adult acted as a bearer of an ideal form, such as reflection. Thus, as noted by Vygotsky, the developmental paradox is reproduced: what should be the end result of development is present from the very beginning and actively interacts with the child.

6. The difficulty in differentiating emotional regulation from the metacognition perspective is also significant. The division of executive functions into cold and hot ones excludes hot regulation from metacognition. However, it should be borne in mind that Vygotsky spoke about the unity of affect and intellect. The conclusion that follows from this context suggests that metacognition should have its own mechanisms of emotional regulation, since communicative interaction should generate appropriate emotional experiences and their reflection.

Conclusion

We sought to show that the results of the studies presented in the review are consistent with the cultural-historical paradigm if we consider executive and metacognitive processes as analogs of such components of higher mental functions as awareness and voluntariness. In this case, executive functions and metacognitive processes turn out to be structural units of a single mechanism for behavior control. This unification is supported by the fact that a number of authors include metacognition as part of executive functions.

The materials presented in the review note the influence of social factors on the development of metacognition and executive functions, such as, for example, the parents' responsiveness, the nature of communication between parents and children, and the level of their education. According to Vygotsky, higher mental functions first originate as forms of communication between people, and only then are they transformed into mental formations. Therefore, the influence of social factors on the development of metacognition and executive functions established in the reviewed studies can be interpreted in favor of the cultural-historical paradigm, *i.e.*, in favor of the fact that metacognition and executive functions are part of higher mental functions.

Conflict of Interest

The authors declare no conflict of interest.

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Original manuscript received August 11, 2023
Revised manuscript accepted November 10, 2023
First published online December 30, 2023

To cite this article: Veraksa, A.N., Veraksa, N.E. (2023). The Interconnection of Metacognition and Executive Functions in Childhood: A Cultural-Historical Perspective. *New Ideas in Child and Educational Psychology, 3*(3–4), 43–65. DOI: 10.11621/nicep.2023.0503