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Music–L2 transfer through executive functions: a narrative review with a focus on inhibitory control

1. Introduction and theoretical framework

The cognitive demands of bilingualism require the constant suppression of the non-target language in order to maintain fluency. Similarly, proficient instrumental performance requires high-level motor inhibition to manage complex fine motor movements and timing. This suggests a potential cognitive overlap in which inhibitory control (IC) functions as a shared resource between musical and linguistic proficiency. As part of an ongoing research programme investigating the relationship between music and L2 learning, this paper explores the biochemical and neurochemical foundations of differences in inhibitory control. The primary objective is to determine whether the motor inhibition developed through fine finger movements during instrumental performance correlates with the associative or linguistic inhibition used in second language learning.

The authors aim to clarify the differences between anatomical and neurological pathways by identifying the neural substrates and networks involved in motor and linguistic inhibitory control. This paper investigates the extent to which instrumental musical practice and second language (L2) acquisition share underlying inhibitory control systems or neurochemical mechanisms. If these mechanisms are functionally or chemically analogous, it stands to reason that musical training may facilitate L2 learning through enhanced inhibitory control. Conversely, if these processes rely on distinct chemical pathways, the hypothesis that inhibitory control advantages are the primary factor driving the superior performance of musically trained individuals in linguistic tasks must be reconsidered.

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The discussion focuses on the hypothesis that intensive experience in one domain, namely music, may lead to measurable advantages in another domain, namely L2 learning. As part of a broader research programme aimed at identifying the main factors underlying the correlation between musical and language skills, this paper specifically investigates inhibitory control. We hypothesise that this transfer of skills is mediated by the functional enhancement of inhibitory control networks supported by specific neurological and neurochemical adaptations.

A growing body of research across various domains highlights a significant correlation between musicality and second language (L2) acquisition (Abutalebi et al., 2008; Chobert–Besson, 2013). The literature suggests that musical training has a profound impact on auditory processing, resulting in enhanced perceptual abilities, superior memory retention, and increased sensitivity to spectro-temporal changes. These neurocognitive advantages enable individuals to detect subtle phonetic variations more effectively, thereby facilitating greater success in L2 learning (Bidelman et al., 2011; Dabóczy, 2019).

This paper aims to determine whether the neurological demands of instrumental musical performance, specifically the suppression of interference and task switching, can map onto the phonetic, syntactic, and lexical processing required for L2 mastery. In this work, we investigate whether the high-level motor inhibition required during instrumental performance acts as a catalyst for the cognitive mechanisms underlying bilingualism. Specifically, we examine whether the discipline involved in suppressing habitual motor responses in music enhances the inhibitory control necessary for successful language switching.

2. The role of inhibitory control in music and language

Inhibition is a complex electrochemical process mediated by a diverse range of receptors and neural circuits. In the mammalian brain, specialized inhibitory interneurons selectively innervate specific regions of the somatodendritic surfaces of both principal cells and other interneurons. Upon activation, these neurons exert inhibitory control through diverse structural and functional mechanisms. This process is inherently plastic and can be modified by learning. As Jonas and Buzsaki (2007) note, even in the simplest pairing of a principal cell and an interneuron, the pattern of firing depends on the precise wiring scheme. While excitatory signals are primarily driven by pyramidal cells, inhibition is localized and specialized, allowing neural systems to suppress specific actions or competing signals.

Inhibitory circuits involved in the modulation of motor, auditory, and visual stimuli are distributed across multiple neural structures, including thalamic and cortical networks. Different domains of principal cells exhibit distinct functional dynamics, contributing to neuronal networks characterized by multiple levels of excitatory and inhibitory interaction. Such configurations support highly resilient biological systems. At the molecular level, inhibition may also involve enzyme inhibitors, which bind to enzymes and reduce their catalytic activity by decreasing substrate–enzyme compatibility. This prevents or slows biochemical reactions and reduces the overall rate of product formation (Tiego et al., 2018).

The brain is a dynamically active organ whose functions depend on complex electrochemical processes. As the fundamental building blocks of cognitive mechanisms, cells enable human behaviour through regulated chemo-electrical messenger systems that support communication between neurons and other cellular structures (Choudhury et al., 2018). Instrumental musical training provides a useful model for investigating practice-induced neuroplasticity, particularly in relation to bimanual hand coordination. This skill requires high-level motor synchronization and robust interhemispheric communication. Interhemispheric inhibition is also a critical cortical mechanism involved in both motor execution and language production (Kuo et al., 2019).

The literature suggests that inhibitory control (IC) is a critical component of successful musical performance (Moreno et al., 2014; Moreno–Farzan, 2015; Medina–Barraza, 2019; Hennessy et al., 2019). Multilingual speakers must continuously regulate language production by inhibiting lexical competitors from both target and non-target languages. It is well established that multilingual individuals rely on IC for language control, particularly when suppressing one language while using another (Dijkstra–van Heuven, 1998; Green, 1998). Empirical evidence further indicates that bilinguals manage language interference by recruiting executive control regions that are essential for inhibiting the production of non-target words. Abutalebi and colleagues (2008) argue that language selection functions as a cognitive mechanism that determines which language is active at a given moment. This process enables bilingual speakers to communicate in the target language while minimizing interference from the non-target language.

Response inhibition, also referred to as behavioural inhibition or prepotent response inhibition, involves the deliberate suppression of actions that are no longer appropriate in a given context. One subtype is motor inhibition, which involves the cancellation of a prepared physical movement in response to changing internal goals or external demands. Attentional inhibition, often termed interference control or interference suppression, enables individuals to ignore distracting environmental stimuli and suppress task-irrelevant cognitive processing in order to maintain focus on primary goals. Although terminology varies across authors and fields, the core distinction lies between attentional mechanisms, which filter information, and behavioural mechanisms, which suppress actions.

Human beings are complex biochemical organisms governed by integrated neural network systems. At birth, certain networks, especially those within the autonomic nervous system, are already functionally mature and support essential life processes without explicit training. In contrast, somatic and cognitive systems depend strongly on activity-dependent plasticity. Their networks are refined through experience, leading to enhanced capabilities in specific domains.

A fundamental feature of auditory information processing, relevant to both music and language, is lateral inhibition within auditory structures. Research on the "inhibitory control advantage" highlights the plasticity of the central auditory system. Reduced auditory nerve input, for example, may trigger a significant shift in the balance between excitation and inhibition within the neural framework (Pantev et al., 2012).

The neuroanatomical circuitry of inhibitory control is primarily mediated by fronto-basal ganglia networks, which enable the rapid suppression of initiated or prepotent motor responses. This process involves a fast signalling route known as the hyperdirect pathway, which bypasses the striatum and allows immediate action control. The efficiency of inhibitory control depends on the balance between excitatory and inhibitory neurotransmitters, particularly within the prefrontal cortex and the striatum.

From a mechanistic perspective, inhibitory control involves both neural signalling and neurochemical modulation. The neural aspect includes top-down inhibitory signals, for example from the pre-supplementary motor area to the subthalamic nucleus, while the chemical aspect involves GABA-mediated filtering and dopaminergic modulation. In music, this inhibitory flow is often synchronized with rhythmic entrainment and motor timing, whereas in L2 use it is driven by linguistic monitoring, lexical selection, and language switching. Comparing these domains therefore requires attention to how striatal dopamine regulates the threshold for inhibitory signals in both high-demand musical and linguistic tasks.

At the cellular level, enzymes act as primary catalysts of biological processes. Their activity can be modified by molecules categorized as activators or inhibitors, depending on whether they increase or decrease reaction rates. Mäntsälä and Niemi (2009) emphasize the importance of catalysis in ensuring that biochemical reactions occur at speeds compatible with physiological requirements.

Table 1. Neurochemical modulation of inhibitory control in music and language

Feature	Music performance	Second language (L2) use
Suppression target	Proactive interference from previous phrases, motor habits	Interference from the native language (L1) or competing lemmas
Chemical driver	Dopamine-heavy reward / timing loops in the striatum	Acetylcholine-modulated attentional switching in the PFC
IC demand	Real-time suppression of "false" notes or unintended tempo deviations	Suppression of non-target language phonology and syntax

Inhibitory functions are frequently categorized according to their specific operational roles, suggesting a fractionation of inhibitory processes. These include automatic and effortful inhibition, which distinguish between subconscious and conscious control; behavioural and response inhibition, which involve the suppression of physical actions or motor outputs; cognitive inhibition, which refers to the modulation of mental representations and thoughts; interference control, including resistance to proactive interference and prepotent response inhibition; and attentional mechanisms, such as inhibition of return. Furthermore, the structural framework of inhibition is often debated through two main paradigms: the one-factor model and the multi-factor model.

The one-factor model posits that inhibitory control follows a single, unified developmental trajectory governed by a central mechanism. The multi-factor model proposes that multiple distinct resources contribute to inhibitory function. According to Howard and colleagues (2014), this model suggests that different components of inhibition follow divergent developmental paths and maintain unique relationships with other cognitive domains.

The human brain undergoes a highly orchestrated developmental process both in utero and after birth, characterized by the generation, migration, and fine-tuning of neurons (Vasung et al., 2019). Learning and environmental interaction drive the modification of neuronal circuits, whereby the dynamic state of local networks is associated with activity-dependent, long-term changes in neural response properties. However, as Galuske et al. (2019) note, these use-dependent modifications must be gated in order to prevent irrelevant activity from inducing inappropriate changes.

Within subcortical structures, the left caudate nucleus plays a critical role in inhibitory control, particularly in managing verbal interference during language switching (Green–Abutalebi, 2013). The functional efficiency of the left caudate is closely associated with a broader regulatory network that includes the dorsolateral prefrontal cortex (DLPFC), anterior cingulate cortex (ACC), supplementary and pre-supplementary motor areas (SMA/pre-SMA), insula, and inferior frontal gyrus (Zboray, 2007; Niendam et al., 2012).

At the biochemical level, inhibitory processes may also be discussed in terms of enzyme regulation, although this should be distinguished from inhibitory control as an executive function. Enzyme inhibition is generally classified into two broad categories — reversible and irreversible — distinguished by the dissociation rate of the enzyme–inhibitor complex.

Reversible inhibitors associate with enzymes through non-covalent interactions, including hydrogen bonds, hydrophobic interactions, and ionic bonds. Because these forces are relatively weak, the inhibitor can dissociate rapidly from the enzyme, allowing dynamic modulation of enzymatic activity. In contrast, irreversible inhibitors typically form stable covalent bonds with specific functional amino acid residues within the enzyme. These complexes dissociate very slowly, if at all, resulting in a permanent or long-term loss of enzymatic function.

3. Neurological correlates

The manifestation of both linguistic expression and musical interpretation is mediated by complex, multi-level neural control systems in which stored cognitive schemas play a foundational role.

1) Sensorimotor integration and cognitive control: acquiring proficiency in a musical instrument involves the intensive engagement of diverse sensorimotor processes. This developmental trajectory relies heavily on executive functions, most notably inhibitory control and cognitive flexibility, including task switching.

2) Hierarchical motor organization: the mechanics of performance, such as striking a piano key or fingering a violin string, are organized through a hierarchical motor structure. Initial motor commands often involve generalized muscle activation; for example, the primary motor cortex may trigger a broad contraction of the hand (Fonyó, 2011). The precision required to produce a single note is achieved through a sophisticated process of selective inhibition, in which the nervous system actively suppresses the movement of non-target digits while modulating the velocity and force of the intended action.

3) Automatization and conditioning: as performers advance towards mastery of complex repertoires, such as classical compositions, the transition from effortful execution to automatized processing becomes increasingly evident (Zboray, 2007). This stage is characterized by conditioned motor sequences, that is, the transformation of individual movements into fluid, “chunked” units of action, and conscious modulation, a hybrid state in which high-level artistic intention provides a supervisory framework for deeply ingrained motor responses.

4. Inhibitory control in instrumental musical training and L2 learning

The neurological overlap between speech and music lies in their shared reliance on hierarchical structures, the refinement of motor output through inhibition, and the transition from conscious schema-building to expert automaticity. The development of musical proficiency is characterized by the formation of complex motor chunks and schemas. This process involves the progressive habitualization of kinetic sequences, resulting in a marked decrease in top-down cognitive load as movements reach a state of automaticity. While the structural parallels between music and language processing are well documented, the specific impact of kinetic automatization on executive functions remains an emerging field of inquiry.

The central hypothesis is that the extensive memorisation and automatization of movement sequences involved in musical training may support the executive suppression processes required in bilingual language use. By mastering the kinetic inhibition of musical schemas, individuals may develop a more robust cognitive architecture for managing linguistic interference.

Inhibition within the central nervous system is a complex regulatory process mediated by diverse neurochemical and electrochemical pathways. Neurotransmitters serve as the primary chemical messengers in this system, modulating the threshold for neuronal activation and suppression.

Key neurochemical agents involved in these inhibitory mechanisms include acetylcholine, dopamine, GABA, glutamate, and serotonergic pathways originating in the raphe nuclei. Research suggests that imbalances within these systems may significantly impair cognitive performance. More specifically, disruptions in cholinergic, glutamatergic, dopaminergic, and GABAergic regulation can affect the functional integrity of working memory. Such neurochemical dysregulation may reduce the capacity to maintain verbal fluency, as the executive processes required for rapid linguistic retrieval, selection, and maintenance become compromised.

5. The neurochemistry and structural organization of kinetic inhibition in musical performance

The execution of complex motor sequences required for musical performance relies on a sophisticated system of kinetic inhibition. This process involves the hierarchical and parallel organization of the motor system, ranging from the cerebral cortex to peripheral proprioceptors. Key subcortical structures, particularly the putamen and the caudate nucleus, play an important role in regulating both kinetic and stabilizing movements.

The neurochemical foundations of kinetic inhibition are characterized by interactions among several neurotransmitter systems. While GABA, or gamma-aminobutyric acid, acetylcholine, dopamine, and glutamate are all involved in motor control and language-related executive processes, musical performance appears to engage a particularly broad neurochemical network. Music can influence human neurochemistry through several distinct mechanisms. Research indicates that music processing engages the nucleus accumbens, leading to dopaminergic activation (Fonyó, 2011; Világi–Tarnawa, 2013). In the midbrain, musical stimuli may also contribute to pain modulation through opioid-related mechanisms. Furthermore, the integration of movement with music may trigger the release of endogenous opioids. Music also affects arousal systems by stimulating neurotransmitter networks in which dopamine and norepinephrine play important roles (Lehrer, 2011; Gangrade, 2012).

Kinetic inhibition is not a localized event but an integrated systemic function. Motor organization follows both hierarchical and parallel pathways involving:

1. the cerebral cortex, responsible for high-level planning and initiation;
2. the basal ganglia, particularly the putamen and caudate nucleus, involved in fine-tuning and inhibitory control;
3. the thalamus and cerebellum, involved in coordination and sensorimotor integration;
4. the brainstem and spinal cord, responsible for signal transmission and reflexive adjustments; and
5. proprioceptors, which provide real-time feedback for postural and kinetic correction.

Current research in bilingual language processing indicates that both languages remain active and accessible simultaneously (Bialystok et al., 2004; Costa, 2005). To prevent cross-linguistic interference, the cognitive system relies on associative or attentional inhibition. A critical hub for this process is the left caudate nucleus, which has been implicated in managing verbal interference and exerting inhibitory control over the non-target language.

Inhibitory signals are processed through complex subcortical pathways that may be described in terms of two broad architectural formats. The first is an associative closed-loop system, a comprehensive pathway that contributes to attentional inhibition. In simplified terms, the signal travels through interconnected structures including the cerebellum, striatum, globus pallidus pars externa (GPe), subthalamic nucleus (STN), substantia nigra pars reticulata (SNr), globus pallidus pars interna (GPi), and thalamus. The second is a more direct open-ended route, a streamlined pathway involving fewer processing stages. This route may be associated with more rapid and less extensively modulated signal transmission.

6. Comparative neurochemistry and synaptic classification

While language and music production share overlapping motor and associative pathways, they may differ in their specific neurochemical profiles. Both systems are activity-dependent, yet they differ in terms of:

– **Neurotransmitter and receptor profiles:** variation in the types of chemical messengers and receptors involved;
– **Temporal dynamics:** differences in neurotransmitter release, reuptake, receptor activation, and synaptic modulation;

– **Structural distribution:** differences in the density and localization of receptors across synaptic environments.

Two broad synaptic environments can be distinguished on the basis of location and functional role. Type I, or peripheral synapses, are found in the musculature as neuromuscular junctions and are responsible for the execution of motor tasks. Type II, or central synapses, are located within the brain and are involved in associative processing, selection, and inhibitory control during production tasks.

Table 2. Comparative analysis of motor and associative tracks

Feature	Motor track	Associative track
Primary function	Physical execution of speech and music	Inhibitory control and selection
Anatomical focus	Muscle-level synapses (Type I)	Central brain synapses (Type II)
Complexity	Direct, action-oriented	Multi-stage, feedback-dependent
Inhibitory hub	Premotor cortex / basal ganglia	Left caudate / thalamocortical loops
Chemical basis	Current-dependent; rapid turnover	Complex receptor-density; variable lifespan

Table 3 provides a comparative analysis of motor (kinetic) and associative inhibition across various neurobiological parameters.

Table 3. Motor and associative inhibition

Parameter	Motor (kinetic) inhibition	Associative inhibition
Anatomical distribution	Cortical and spinal circuits, medulla, and neuromuscular junctions	Primarily localized within the brain, including association cortex and prefrontal cortex
Primary neurochemistry	Predominantly acetylcholine (ACh)	Complex diversity: GABA, glutamate, dopamine, serotonin, etc.
Ionic flux	Sodium, potassium, and calcium dependent	Sodium, potassium, and calcium dependent
Signal mechanism	Activity-dependent electrochemical signalling	Activity-dependent electrochemical signalling
Receptor types	Specific nicotinic acetylcholine receptors (nAChRs)	Broad range of ionotropic receptors (nACh, 5HT3, NMDA)
Receptor density	15,000–20,000 receptors per joint / junction (can exceed 1,000,000 at end plates)	Highly variable / unknown; typically lower density than NMJ
Functional lifespan	Approximately 8–10 days	Approximately 3–10 hours

The motor association area in the cerebral cortex coordinates skeletal muscle movements, while the primary somatosensory cortex and sensory association areas process input from the skin and musculoskeletal system. The primary motor cortex serves as a central platform for executing the precise motor actions required to play a musical instrument.

The mechanical action of pressing a violin string, for example, is mediated through descending motor pathways, including the pyramidal tract, and ultimately through neuromuscular junctions, where acetylcholine functions as the primary neurotransmitter. In contrast, language selection and the inhibition of non-target languages rely on central neural networks involving cortical and subcortical structures. These cognitive processes are regulated by several neurotransmitter systems, including serotonergic, dopaminergic, glutamatergic, cholinergic, and GABAergic mechanisms, while GABA and glycine serve as principal inhibitory neurotransmitters in the nervous system.

Although there are clear neural overlaps between brain regions involved in musical performance and language production, the precise mechanisms by which expertise in one domain may enhance performance in the other, particularly with regard to inhibitory control during reading and language processing, remain an area of active investigation.

Shared neural architecture: both language and music engage partially overlapping networks, including regions such as Broca’s area, or the left inferior frontal gyrus, and posterior temporal regions, which are involved in hierarchical, sequential, and syntactic processing.

Decoding and associative mechanisms: fast decoding of musical notation and fluent text reading may rely on partly similar associative mechanisms and high-speed visual-perceptual expertise. Musical training has also been associated with changes in left-hemisphere activation, suggesting that these tasks may share pathways involved in rapid information processing.

Kinetic skills and motor inhibition: playing an instrument and producing speech both require sophisticated kinetic skills and the suppression of unwanted physical responses. Expert musicians often demonstrate enhanced motor inhibitory control and task-specific modulation of motor cortical activity compared with non-experts.

The link between inhibitory types: despite these parallels, there is currently limited direct evidence linking motor inhibition, understood as the suppression of physical movement, to associative inhibition, understood as the suppression of irrelevant mental associations. While musical training may improve aspects of general inhibitory control, its specific transfer to associative or linguistic inhibition requires further empirical investigation.

Neurological foundations: at the cellular level, fundamental electrochemical processes, such as sodium and potassium ion exchange, are common to neural signalling. However, neurotransmitters and their receptors are highly specialized across neural systems, allowing distinct functional roles within music- and language-related networks.

7. The role of inhibitory control in music-to-language transfer

While systematic instrumental musical training is often credited with enhancing executive functions, the hypothesis that enhanced inhibitory control (IC) directly facilitates second language (L2) performance remains a matter of neurobiological debate. This analysis explores why a direct causal link based specifically on IC mechanisms appears unlikely when examined through the lens of neurochemistry and motor habitualization.

1) Shared associative mechanisms

There is a degree of cognitive overlap in the foundational processing of music and language, as both domains rely on partially shared neural mechanisms. Rapid decoding in both musical notation and orthographic text involves comparable associative processes related to pattern recognition. In addition, both language production and instrumental performance require sophisticated motor coordination, high-level sequencing, and the suppression of irrelevant or competing responses.

2) Divergent inhibitory architectures

Despite these surface-level similarities, the underlying neurological operations of inhibitory control appear to rely on partly distinct pathways.

First, in instrumental musical performance, IC is strongly associated with neuromuscular response inhibition. This involves the suppression of habitual motor responses, allowing performers to override physical "autopilot" and execute intentional expressive or technical changes.

Second, in linguistic contexts, L2 performance relies more heavily on attentional and cognitive inhibition. This includes the suppression of the dominant language or competing linguistic structures and is mediated by central neural networks involved in lexical selection, language switching, and interference control rather than by strictly motor-based suppression.

3) Biochemical and electrochemical constraints

From a biochemical and electrochemical perspective, the transfer of expertise between these two systems faces important constraints. Although neuroimaging studies confirm partially shared activation in certain cortical areas, such as Broca's area and the prefrontal cortex, the specific network architecture required for music-trained IC to directly enhance L2 inhibitory mechanisms has not yet been established. The neurochemical profiles of motor-response inhibition and cognitive-linguistic inhibition suggest that these systems may operate through different regulatory mechanisms. Therefore, a broad cross-domain enhancement of IC should be treated as a tentative hypothesis rather than an established explanation.

8. Conclusion

Musical training undoubtedly refines the brain's ability to manage motor sequences, auditory processing, and sensory decoding. However, the claim that it directly improves L2 proficiency through enhanced inhibitory control is likely limited by the specialised nature of neural inhibition. The overlap between music and language may be more closely related to general cognitive engagement, auditory sensitivity, pattern recognition, attention, and associative learning than to the direct transfer of inhibitory circuitry.

Research suggests that some cognitive processes cultivated through music education, such as musical notation decoding, sight-reading, temporal pattern recognition, and the structural analysis of compositions, may provide useful support for L2 learning. These processes may be more relevant to L2 success than the motor inhibition involved in vocal or instrumental performance alone.

9. Limitations and future directions

While both speech and musical performance involve complex motor responses and partially shared neural pathways for sequencing and conceptual processing, their production mechanisms differ in important ways. Language production depends heavily on associative and attentional inhibitory control, whereas expert-level instrumental musical performance is strongly motor-dependent. Consequently, the present analysis suggests that long-term expertise in one domain may not produce a cross-domain advantage specifically through inhibitory control. These findings highlight the need for further research into the distinct cognitive intersections of music and language.

The primary focus of this paper is to clarify differences in the neurochemistry and mechanisms of inhibitory control within the broader research area exploring the relationship between musicality and multilingualism. As part of an ongoing long-term study, the authors aim to identify the mechanisms that may enable musically trained individuals to outperform their peers in second language tasks by systematically evaluating several possible explanations. The specific aim of the present paper was to determine whether there is a direct link between enhanced IC developed through instructed classical musical training and instructed L2 acquisition. However, by comparing the mechanisms and neurochemistry of motor-based and language-related inhibitory control, the authors found no sufficient evidence for such a direct link. Therefore, this particular explanation is not considered a strong candidate for further investigation within the present research programme.

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Music–L2 transfer through executive functions: a narrative review with a focus on inhibitory control

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Extant literature suggests that musical training may enhance second-language (L2) acquisition and instructed L2 learning, with musically trained individuals often outperforming their peers in tasks requiring inhibitory control (IC). This observed cognitive advantage is frequently attributed to a shared, domain-general resource. Drawing on literature on IC in relation to musical training (D'Souza et al., 2018; Cores-Bilbao et al., 2019), we theorised that the cognitive overlap between music and instructed language learning might arise from inhibitory control developed through instrumental musical training and that this could serve as a catalyst for L2 learning. The main aim of this discussion is to clarify whether enhanced IC acquired during instructed instrumental musical training can be considered responsible for advantages in L2 learning.

The neural mechanisms of inhibitory control are essential for the continuous suppression of non-target lexical competitors in bilingualism (Abutalebi–Green, 2007; Zendel–Alain, 2009; Schön–Tillmann, 2015; Patel–Morgan, 2016). Inhibitory control also supports the management of motor inhibition required in instrumental musical performance. However, these two processes differ in important ways. As part of a broader investigation, this paper examines why the neurochemical foundations of IC may not provide a direct bridge between music and L2 learning, with particular attention to why IC developed through practical instrumental musical training may not function as a major amplifier of L2 success. While language production and musical performance are governed by partly distinct neurocognitive mechanisms — associative inhibitory control and high-level motor control, respectively — this paper argues that music may nevertheless function as a powerful cognitive scaffold for linguistic development.

Keywords: *musical training, second language learning, inhibitory control, executive functions, neurochemical mechanisms, language control, music–language transfer.*

Трансфер між вивченням музики та другої мови через виконавчі функції: огляд наукової літератури з фокусом на інгібіторному контролі

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Сучасна наукова література свідчить, що вивчення музики може сприяти засвоєнню другої мови (L2) та інституційно організованому навчанню другої мови, причому особи з музичною підготовкою часто демонструють кращі, ніж їхні однолітки, результати у завданнях, що потребують інгібіторного контролю (IC). Цю виявлену когнітивну перевагу часто пояснюють спільним, доменно-загальним ресурсом. Спираючись на літературу про інгібіторний контроль у зв'язку з музичним навчанням (D'Souza et al., 2018; Cores-Bilbao et al., 2019), ми припустили, що когнітивне перетинання між музикою та інституційно організованим вивченням мови може виникати завдяки інгібіторному контролю, сформованому під час навчання гри на музичному інструменті, і що такий трансфер може слугувати каталізатором для вивчення L2. Основна мета публікації полягає в тому, щоб з'ясувати, чи можна вважати посилений інгібіторний контроль, набутий під час інституційного навчання гри на музичному інструменті, відповідальним за переваги у вивченні L2.

Нейронні механізми інгібіторного контролю є важливими для постійного пригнічення нецільових лексичних конкурентів у білінгвізмі (Abutalebi–Green, 2007; Zendel–Alain, 2009; Schön–Tillmann, 2015; Patel–Morgan, 2016). Інгібіторний контроль також підтримує керування моторним гальмуванням, необхідним для інструментального музичного виконання. Однак ці два процеси істотно відрізняються. У межах ширшого дослідження ця стаття розглядає, чому нейрохімічні основи інгібіторного контролю можуть не забезпечувати прямого зв'язку між музикою та вивченням L2, приділяючи особливу увагу тому, чому інгібіторний контроль, сформований у процесі практичного навчання гри на музичному інструменті, може не функціонувати як головний чинник посилення успішності у вивченні L2. Хоча мовлення та музичне виконання керуються частково відмінними нейрокогнітивними механізмами — відповідно асоціативним інгібіторним контролем і високорівневим моторним контролем, — у статті стверджується, що музика все ж може функціонувати як потужна когнітивна опора для мовного розвитку.

Ключові слова: *музичне навчання, вивчення другої мови, інгібіторний контроль, виконавчі функції, нейрохімічні механізми, мовний контроль, трансфер між музикою та мовою.*

A zenei képzés és a másodiknyelv-tanulás közötti transzfer a végrehajtó funkciók tükrében: szakirodalmi áttekintés a gátló kontroll fókuszával

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A meglévő szakirodalom arra utal, hogy a zenei képzés elősegítheti a második nyelv (L2) elsajátítását és az intézményes keretek között zajló másodiknyelv-tanulást. A zenei képzésben részesült személyek gyakran jobb teljesítményt nyújtanak társaiknál olyan feladatokban, amelyek gátló kontrollt (*inhibitory control*) igényelnek. Ezt a megfigyelt kognitív előnyt gyakran egy közös, doménáltalános erőforrással magyarázzák. A zenei képzés és a gátló kontroll kapcsolatára vonatkozó szakirodalomra támaszkodva (D'Souza et al., 2018; Cores-Bilbao et al., 2019) azt feltételeztük, hogy a zene és az intézményes nyelvtanulás közötti kognitív átfedés a hangszeres zenei képzés során fejlődő gátló kontrollból eredhet, és ez katalizátorként hathat az L2-tanulásra. A tanulmány fő célja annak tisztázása, hogy az intézményes hangszeres zenei képzés során megerősödő gátló kontroll tekinthető-e felelősnek a másodiknyelv-tanulásban megfigyelhető előnyökért.

A gátló kontroll idegrendszeri mechanizmusai alapvető szerepet játszanak a nem célnyelvi lexikai elemek folyamatos deaktivációjában a kétnyelvűek mentális lexikonjában (Abutalebi–Green, 2007; Zendel–Alain, 2009; Schön–Tillmann, 2015; Patel–Morgan, 2016). A gátló kontroll ugyanakkor a hangszeres zenei előadáshoz szükséges motoros gátlás irányítását is támogatja. A két folyamat azonban fontos szempontokból eltér egymástól. Egy tágabb kutatás részeként a tanulmány azt vizsgálja, hogy a gátló kontroll neurokémiai alapjai miért nem feltétlenül teremtenek közvetlen hidat a zene és az L2-tanulás között. Különös figyelmet kap az a kérdés, hogy a gyakorlati hangszeres zenei képzés során fejlődő gátló kontroll miért nem működhet szükségszerűen a másodiknyelv-tanulási siker egyik fő erősítő tényezőjeként. Bár a nyelvi produkciót és a zenei előadást részben eltérő neurokognitív mechanizmusok irányítják — előbbit elsősorban az asszociatív gátló kontroll, utóbbit pedig a magas szintű motoros kontroll —, a tanulmány amellett érvel, hogy a zene ennek ellenére erőteljes kognitív támaszként szolgálhat a nyelvi fejlődésben.

Kulcsszavak: *zenei képzés, másodiknyelv-tanulás, gátló kontroll, végrehajtó funkciók, neurokémiai mechanizmusok, nyelvi kontroll, zenei–nyelvi transzfer.*