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Galvanic Skin Response Biofeedback in Child Neuropsychology: Foundations, Applications, and Reflections

Biofeedback de Respuesta Galvánica de la Piel en Neuropsicología Infantil: Fundamentos, Aplicaciones y Reflexiones

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Resumen

Este artículo explora las implicaciones del uso del biofeedback de respuesta galvánica de la piel (GSR) en el campo de la neuropsicología infantil. El GSR, como indicador fisiológico de la actividad del sistema nervioso autónomo, proporciona una medida objetiva de la activación emocional, lo que lo convierte en una herramienta valiosa tanto para la evaluación clínica como para la intervención terapéutica. El trabajo revisa los fundamentos neurofisiológicos del GSR y examina sus aplicaciones clínicas en niños con condiciones como el trastorno por déficit de atención con hiperactividad (TDAH), los trastornos de ansiedad, el trastorno del espectro autista (TEA) y las dificultades generales de autorregulación emocional. Entre los beneficios reportados se incluyen mejoras en el autocontrol, reducción de síntomas de ansiedad y estrés, fortalecimiento de los procesos atencionales y mayor motivación a través de formatos terapéuticos interactivos y lúdicos. Sin embargo, el artículo también discute desafíos metodológicos y éticos, como la variabilidad de las señales, la limitada generalización fuera del contexto clínico y la necesidad de contar con evidencia empírica más sólida. La reflexión crítica enfatiza que el biofeedback GSR debe entenderse como una herramienta complementaria, no invasiva y empoderadora dentro de intervenciones neuropsicológicas integradoras, que apoye a los niños en el desarrollo de habilidades de autorregulación duraderas.

Palabras clave: biofeedback; respuesta galvánica de la piel; neuropsicología; autorregulación emocional.

Abstract

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This article explores the implications of using galvanic skin response (GSR) biofeedback within the field of child neuropsychology. GSR, as a physiological indicator of autonomic nervous system activity, provides an objective measure of emotional arousal, making it a valuable tool for both clinical assessment and therapeutic intervention. The paper reviews the neurophysiological foundations of GSR and examines its clinical applications in children with conditions such as attention-deficit/hyperactivity disorder (ADHD), anxiety disorders, autism spectrum disorder (ASD), and general difficulties in emotional self-regulation. Reported benefits include improvements in self-control, reduction of anxiety and stress symptoms, enhancement of attentional processes, and increased motivation through interactive and playful therapeutic formats. However, the article also discusses methodological and ethical challenges, including variability of signals, limited generalization outside clinical settings, and the need for stronger empirical evidence. The critical reflection emphasizes that GSR biofeedback should be understood as a complementary, non-invasive, and empowering tool within integrative neuropsychological interventions, supporting children's development of long-lasting self-regulation skills.

Keywords: biofeedback; galvanic skin response; neuropsychology; emotional regulation.

Introduction

Galvanic Skin Response (GSR) biofeedback is a self-regulation technique that allows individuals to monitor and modify their physiological responses through real-time feedback of bodily signals. In child neuropsychology, the use of GSR biofeedback has gained interest as a therapeutic complement for various disorders, given that many emotional and behavioral problems in children are associated with atypical patterns of autonomic activation. (Kothgassner et al., 2022). For example, children with anxiety may exhibit physiological hyperactivation when exposed to stress, while children with Attention-Deficit/Hyperactivity Disorder (ADHD) may struggle to modulate their level of arousal. GSR biofeedback provides a pathway for children to become aware of their physiological arousal state and to learn strategies for regulating it. This academic article reviews the neurophysiological foundations of GSR, its main clinical applications in the pediatric population (such as in ADHD, anxiety disorders, autism spectrum disorder, and difficulties in emotional self-regulation), the benefits observed in interventions, as well as its limitations and methodological or ethical challenges. Finally, it offers a critical reflection on the role of GSR biofeedback within neuropsychological therapeutic programs for children, emphasizing an integrative and evidence-based perspective.

Neurophysiological Foundations of GSR

Galvanic Skin Response (GSR), also referred to as electrodermal activity (EDA), refers to variations in the electrical properties of the skin in response to the activity of sweat glands. Neurophysiologically, sweat glands—particularly those on the palms of the hands and soles of the feet—are innervated exclusively by the sympathetic nervous system, a branch of the autonomic nervous system involved in "fight or flight" reactions. In response to internal or

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external stimuli that provoke stress, fear, emotional arousal, or cognitive effort, sympathetic activity increases, triggering perspiration on the skin. This microscopic increase in sweating reduces the skin's electrical resistance and therefore increases its electrical conductance. In states of relaxation or positive emotional conditions, the opposite effect occurs: sympathetic activity decreases, the hands dry, skin resistance rises, and conductance falls. These fluctuations can be measured by placing two sensors on the surface of the skin (often on two fingers of the hand) that record changes in microSiemens (μS), the unit of conductance. (Dormal et al., 2021)

From a neural perspective, variations in GSR reflect the coordinated activity of several brain structures related to emotion and attention, primarily within the limbic system and its connections. Regions such as the amygdala, hypothalamus, and the hypothalamic-pituitary-adrenal axis contribute to generating autonomic stress responses that manifest in electrodermal changes. Likewise, prefrontal cortical structures and brainstem areas (including the reticular formation) modulate these responses by integrating cognitive aspects. In sum, GSR functions as a psychophysiological indicator of emotional arousal: its increase is usually associated with anxiety, fear, pain, or mental effort, while reductions in conductance are associated with calmness and relaxation.

In GSR biofeedback, these principles are applied to train individuals to voluntarily control their level of arousal. Through feedback interfaces (visual, auditory, or game-based), the child sees a real-time representation of their skin conductance and, with the therapist's guidance, practices relaxation or concentration techniques to modify that signal in the desired direction (for example, lowering it to achieve relaxation). Over the course of sessions, the goal is for the child to develop greater interoceptive awareness and active self-regulation skills, transferring these achievements to everyday life situations. (Mathias et al., 2023)

Clinical Applications in Children

GSR biofeedback has a range of clinical applications in the pediatric population within the field of neuropsychology. The following are some of the areas where its use has been most frequently explored:

Attention-Deficit/Hyperactivity Disorder (ADHD)

In children with ADHD, GSR biofeedback is used with the aim of improving self-regulation and attention. These children often experience difficulties in controlling their impulses and levels of activity, which may be related to unstable arousal. Training with GSR enables them to recognize when they are "over-excited" or anxious, while learning to apply strategies (such as deep breathing, mindfulness, etc.) to calm their physiological activation. Several programs integrate GSR with other types of biofeedback (for example, heart rate variability or EEG neurofeedback) in order to address the multiple components of ADHD. Clinical reports have

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documented improvements in focus, reductions in impulsivity, and greater emotional control in children with ADHD who undergo biofeedback, as a complement to conventional treatments. Parents and therapists emphasize that the interactive and playful nature of many biofeedback sessions enhances children's motivation by providing them with a "game-like" experience where they earn rewards for maintaining calm and concentration. (Nelson et al., 2020) Although formal empirical evidence specifically on GSR in ADHD remains limited, clinical reports and pilot studies suggest a beneficial potential to help these children internalize self-regulation skills that later translate into improved academic and behavioral performance.

Anxiety and Stress Disorders

Biofeedback interventions have traditionally been used to treat anxiety in children and adolescents, and GSR is a particularly suitable modality for this purpose since it is a direct indicator of nervous tension. Children with generalized anxiety disorder, phobias, performance anxiety, or simply high stress levels may benefit from training to voluntarily reduce their sympathetic activation. In GSR biofeedback sessions aimed at anxiety, children are guided through exercises such as muscle relaxation, diaphragmatic breathing, or guided imagery, while observing on the screen how these methods decrease their skin conductance levels, thereby objectively confirming the sensation of relaxation. Clinical studies have shown that even brief sessions can achieve significant reductions in state anxiety and in the frequency of electrodermal responses to stressors. In broader therapeutic contexts, GSR biofeedback is often combined with cognitive-behavioral therapy: for example, before gradual exposure to a feared situation (such as public speaking), the child is trained to reach a baseline state of calm through physiological feedback. Additionally, in specific contexts such as pediatric dental anxiety, GSR has been investigated as an objective measure to identify and monitor fear in dental consultations. (Padminee et al., 2022). This demonstrates that GSR can serve not only as a training tool but also as an assessment instrument for childhood anxiety in clinical settings, providing therapists and physicians with quantifiable data on a child's level of distress and how it changes with intervention.

Autism Spectrum Disorder (ASD)

Children with autism often present difficulties in emotional regulation and elevated levels of anxiety or stress in response to sensory and social changes. Psychophysiological research indicates that some children with ASD exhibit atypical patterns of electrodermal activity, such as low baseline activation (reduced resting conductance) combined with exaggerated or unusual reactions to specific stimuli. This suggests difficulties in the autonomic system's flexible modulation of arousal. In therapy with children with ASD, GSR biofeedback has been incorporated for two primary purposes: monitoring the child's stress levels during sessions (allowing the therapist to adjust task demands before a dysregulation crisis occurs) and teaching the child or adolescent to identify their emotional states through bodily signals.

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For example, programs have been developed in which a child with ASD uses a portable device that measures GSR; when their arousal exceeds a certain threshold (indicating frustration or sensory overload), the device provides a vibratory or visual cue reminding them to apply a calming strategy (such as retreating to a "quiet corner," practicing deep breathing, or asking an adult for help). This type of real-time biofeedback has shown potential in reducing the frequency and severity of stress-related disruptive behaviors in ASD. Although ASD poses particular challenges (such as children's tolerance of skin sensors or their understanding of the link between emotion and physiological signals), initial findings indicate that, with proper adaptations, many individuals with autism can learn to influence their autonomic responses. (Siepmann et al., 2022). This opens the door to more personalized interventions, where GSR acts as a bridge between behavioral therapies and the child's inner world, making the invisible (their emotions) visible and reinforcing self-control behaviors.

Emotional Self-Regulation and Impulsivity Problems

Beyond specific diagnoses, GSR biofeedback has been used with children who have difficulties regulating their emotions and behaviors. This includes children with frequent temper outbursts, low frustration tolerance, difficulty calming themselves, or controlling aggressive impulses. In these cases, GSR is integrated into psychoeducational programs where the child learns about the mind-body connection. For example, they may be shown how a conflict or an unpleasant memory immediately raises the conductance line on the screen, while techniques such as listening to relaxing music or thinking of something pleasant make it decrease. This awareness process is powerful: children who were previously unaware of the bodily signals of anger or stress begin to recognize them (sweaty hands, racing heart, shallow breathing) and anticipate their reactions. (Thabew et al., 2021)

With guided practice, they manage to implement pauses before reacting impulsively—for instance, stopping to breathe when they see their "level" rising too high instead of hitting or yelling. A recent study with children diagnosed with disruptive behavior disorders (such as oppositional defiant disorder) employed skin conductance level (SCL) biofeedback across 20 sessions, finding that participants learned to self-reduce their activation and that those who were more successful in doing so exhibited greater reductions in aggressive behaviors as reported by parents. These findings underscore that GSR biofeedback can serve as a valuable component within multimodal treatments for self-control difficulties, complementing cognitive and behavioral modification techniques with direct physiological training.

Observed Benefits in Interventions with GSR Biofeedback

The incorporation of GSR biofeedback in child neuropsychological interventions has demonstrated various benefits, supported both by scientific studies and by clinical reports accumulated over recent decades.

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Improvement of self-regulation and self-control: Perhaps the most significant overarching benefit is that children learn to identify and modulate their internal states. Through biofeedback, they develop more refined emotional awareness (recognizing when they are becoming dysregulated before losing control) and acquire "tools" for self-regulation, such as breathing techniques, muscle relaxation, or mindfulness (Klimenko, et al 2025). This translates into better self-control in real-life situations: children report feeling more capable of calming themselves when anxious or angry, thereby avoiding impulsive reactions. Parents and teachers often observe reductions in tantrums, greater patience, and less reactivity after a period of GSR biofeedback training, especially in children with a history of emotional outbursts.

Reduction of anxiety and stress symptoms: Numerous studies have documented that biofeedback (in its different modalities) is effective in reducing anxiety in pediatric populations. In particular, GSR provides a quick pathway to assess anxiety levels and to train their reduction. For example, significant decreases in state anxiety scores and physical stress symptoms (such as muscle tension and headaches) have been observed after 6 to 12 sessions of biofeedback in anxious children, comparable to the results achieved with traditional relaxation techniques. Unlike verbal therapy, biofeedback offers tangible and immediate outcomes (the child sees the curve drop when they succeed in relaxing), which increases their motivation and self-confidence in facing stressful situations independently. (Centers for Disease Control and Prevention, 2022)

Attentional and cognitive improvements: In contexts such as ADHD, beyond behavioral effects, concomitant cognitive benefits have been reported. Better sustained attention, more stable reaction times, and even modest improvements in executive functions have been observed in children with ADHD who complete biofeedback programs (especially when GSR is combined with breathing training or EEG neurofeedback). This may be related to the fact that, by reducing their physiological hyperactivation, children achieve a more optimal state for concentration and information processing. While individual results vary, it has been suggested that GSR biofeedback may indirectly contribute to enhancing academic performance by helping children more easily reach states of calm and focus. (Makaracı et al., 2023)

Playful and motivating therapeutic character: Unlike some traditional interventions, biofeedback sessions are often perceived as a game by children. Many current systems present feedback in the form of video games or interactive challenges (e.g., making a rocket launch by relaxing). This increases adherence and active participation in the therapeutic process. Children are often excited to "play" with their own body responses, which reduces resistance to therapy. Parents have reported that children speak positively about their biofeedback sessions, sometimes without fully realizing that they are in therapy, which facilitates long-term engagement. (Li et al., 2025)

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Non-invasive character and absence of side effects: A key benefit of GSR biofeedback is that it is a safe, painless technique without adverse effects. It does not involve medication or invasive procedures, but only superficial skin electrodes. For this reason, it is well tolerated by most children. This makes it an attractive option for parents and clinicians as a complement or alternative when seeking to minimize exposure to pharmacological treatments (e.g., in anxiety or ADHD). Furthermore, the skills learned tend to be enduring; once the child internalizes how to relax, they generally retain this capacity, requiring only occasional reinforcement sessions. (Ostojict et al., 2022)

In summary, when properly implemented, GSR biofeedback can empower children within their therapeutic process, making them active participants in their own improvement. The benefits range from immediate physiological changes (e.g., lower heart rate and conductance) to medium-term behavioral and emotional transformations, all contributing to better adaptive functioning of the child in different areas of life.

Methodological and Ethical Limitations and Challenges

Despite its advantages, the use of GSR biofeedback in children involves limitations and challenges that must be considered for responsible and effective application:

Individual variability and external factors: GSR signals can fluctuate widely between individuals and even within the same child under different circumstances. Factors such as ambient temperature, hydration level, body movement, or even the child's enthusiasm for the session can affect skin conductance independently of emotional state. This presents a methodological challenge: it is necessary to establish baseline measures and personalized calibrations for each child in each session to correctly interpret changes. The same µS value may indicate different stress levels in two children; therefore, therapy should focus more on patterns of change than on absolute values. (Agbayani et al., 2020). Moreover, movement artifacts or irregular sensor contact can introduce noise into the signal, requiring the therapist to monitor data quality and teach the child to remain relatively still (which can be difficult in young children or those with ADHD).

Generalization of skills beyond the clinical setting: An important question is the extent to which skills learned during biofeedback transfer to real-world contexts. A child may succeed in controlling their GSR in the clinic, under structured conditions and with immediate feedback, but struggle to apply this self-regulation at school or home, where no monitor is available. To mitigate this, strategies such as fading (gradual withdrawal of feedback) and training across multiple contexts are recommended. Nonetheless, some studies have found that biofeedback effects may fade over time if not reinforced; consequently, periodic booster sessions may be required to consolidate gains. (Pazos-Alfonso & Mendoza-Barrera, 2025)

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Sample size and emerging scientific evidence: Although promising studies exist, rigorous controlled research on GSR biofeedback in children remains relatively scarce or limited to small samples. This weakens the strength of conclusions about its overall efficacy. Many reports come from case studies or clinical series without control groups. More research (randomized trials, long-term follow-ups) is needed to define precisely for whom and under what conditions GSR biofeedback is most effective. The lack of standardized protocols (in session duration, number of sessions, and combination with other therapies) complicates comparisons across studies. This methodological challenge highlights the need for unified protocols and best practice guidelines for the use of GSR biofeedback in pediatrics. (Alneyadi et al., 2021)

Ethical considerations and child acceptance: Although the procedure is non-invasive, it is always crucial to obtain the child's assent in addition to parental consent. Some children (especially those with ASD or sensory sensitivities) may feel uncomfortable or anxious about wearing skin sensors. Forcing participation could be counterproductive. Therapists must approach this in a playful and gradual manner, respecting the child's boundaries. Another ethical issue is the privacy of physiological data: these devices collect sensitive information about the child's emotional state, which clinicians must handle confidentially, explaining to families that its use is strictly therapeutic. Likewise, it is important to avoid creating in the child the impression that they are "constantly being monitored" or that they need a device to control themselves—the goal should be for the child to see biofeedback as a temporary aid on the path toward autonomy, not as a permanent prosthesis. (Slavikova et al., 2020). Finally, from an equity perspective, there is the challenge of access: biofeedback technology can be costly or unavailable in certain school or clinical environments, creating disparities in who can benefit. Professionals should advocate for broader dissemination and, if possible, the integration of more affordable tools (e.g., simple wearables) to expand access to these interventions.

Critical Reflection on the Role of GSR in Child Neuropsychology

The incorporation of GSR biofeedback into child neuropsychological programs invites a critical reflection on its true scope and integration. First, what does this technique offer that traditional approaches do not? An evident answer is that it provides an objective physiological dimension to therapeutic work. This is valuable in neuropsychology, a field that by definition seeks to link the mind with the body. GSR allows emotional abstractions to be translated into concrete data, facilitating both psychoeducation (children and parents can visualize stress or calm) and the measurement of progress in addition to subjective scales. From this perspective, GSR enriches the holistic understanding of the child, reminding us that behind every disruptive behavior or attentional difficulty there is an organism self-regulating—sometimes ineffectively—and that intervening at this physiological level can enhance outcomes.

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Nevertheless, it is crucial to recognize that GSR does not act in isolation. The best results are observed when biofeedback is integrated within multimodal interventions. For example, a child with ADHD may benefit more if, in addition to GSR training for relaxation, they receive coaching in executive skills and behavioral adaptations in the classroom. Similarly, a child with social anxiety will also require cognitive work on fearful beliefs and gradual exposure. GSR thus functions as a synergistic component: it improves the child's receptivity to other techniques (since they are calmer and more attentive) and provides an additional coping tool. However, it should not be considered a replacement for fundamental therapies, but rather a complementary element that, in certain cases, makes the difference between a purely verbal/cognitive approach and a truly biopsychosocial one.

Another critical consideration is suitability according to age and child profile. Literature and clinical experience suggest that children from approximately six to seven years of age can meaningfully engage in GSR biofeedback, but for younger children its usefulness is questionable, as they may not understand the stimulus–response connection or may lack the patience required for sessions. Likewise, for some children, focusing on bodily sensations may even be counterproductive (for instance, those with somatoform disorders or hypochondria might become overly fixated on physical symptoms). (Umaç et al., 2023). Therefore, clinicians must individualize recommendations, taking into account motivation, cognitive capacity, and the child's characteristics. Implementing GSR indiscriminately, driven only by its technological novelty, would be a mistake. Professional reflection entails asking: Will this particular child truly benefit from visualizing their galvanic response, or are there other therapeutic priorities? In some cases, prioritizing family, school, or pharmacological interventions may take precedence, with biofeedback occupying a secondary role.

Finally, from an ethical and practical perspective, the sustainability of GSR use must be considered. Technological advances are giving rise to increasingly portable and user-friendly devices (bracelets, watches) that could allow biofeedback to be integrated into the child's natural environment. While promising, this remains in its infancy. The constructive critique here is: how prepared is the field of neuropsychology to adopt such innovations? Specialist training, validation of apps and devices, and clear guidelines for their use outside the clinic (tele-biofeedback, etc.) will be required. The risk to avoid is that the technology becomes fashionable without sufficient clinical backing, leading to skepticism if outcomes do not meet inflated expectations. Thus, advocating for evidence-based implementation is central to this reflection: neuropsychologists must remain up to date with emerging research on biofeedback, while maintaining a healthy degree of skepticism in line with available data.

In conclusion, GSR biofeedback in child neuropsychology represents a valuable tool but one that reaches its full potential only within an integrative paradigm. Its greatest achievement is not merely lowering the conductance of an anxious child during a session, but contributing to the development of internal resources and bodily awareness that can serve them throughout

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life. When we achieve that goal—seeing the child empowered, saying "I know how to calm myself when I feel nervous"—we can affirm that the role of GSR has been truly meaningful in their therapeutic process.

Conclusions

Biofeedback based on galvanic skin response provides an innovative neurophysiological dimension to the treatment of childhood psychological difficulties. Its neurobiological foundations position it as a sensitive indicator of emotional arousal, and its clinical application has demonstrated benefits in disorders such as ADHD, anxiety, autism, and general self-regulation problems. Documented positive outcomes include improvements in self-control, reductions in anxiety, enhanced attention, and playful learning of coping skills. However, important limitations have also been identified: individual variability in signals, the need for more robust evidence, and practical challenges regarding generalization and acceptance by some children.

Overall, GSR biofeedback should be understood as a complementary tool within the therapeutic arsenal of child neuropsychology. When employed with clinical judgment, integrated into comprehensive interventions, adapted to the characteristics of the child, and accompanied by close professional guidance, it can significantly enrich therapeutic programs, providing a tangible bridge between the physiological and the psychological. Critical reflection calls for using this technology responsibly and in a personalized manner, avoiding both overestimation and neglect due to lack of knowledge. Ultimately, the goal is for GSR biofeedback to empower children in their own process of change, helping them take control of their bodily responses and, consequently, of their emotions and behaviors. As research and practice continue to advance in parallel, the field will be able to define more clearly the optimal role of GSR in child neuropsychology, ensuring that this promising technique benefits those who need it most in an ethical, effective, and lasting manner.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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