

Impacts of Early Intervention Plans on Cognitive and Socio-emotional Development in Down Syndrome Patients

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ABSTRACT: This literature review explores the effects of early intervention and its impacts on cognitive and socio-emotional development in infancy and early childhood with Down Syndrome. Being a neurobiological disorder, it affects key areas of cognitive and socio-emotional functioning. As a disorder characterized by its congenital nature, key developmental phases wherein emotional, social, and cognitive skills are meant to mature are inevitably affected. This leads to irregularities in behavioral traits, emotional perception, interpersonal and situational interaction and awareness, and more, which present significant barriers to maintaining a successful professional lifestyle and an emotionally fulfilling personal and social lifestyle. While the structural differentiations are incurable, early intervention plans targeted at the cognitive and socio-emotional consequences of these structural differentiations, implemented in the early stages of Down Syndrome, at infancy and childhood, can support and enhance development, showcasing short-term and long-term benefits. This literature review posits that while there are varied results to early intervention plans and treatment plans that focus on supporting development at early stages to take advantage of the neuroplasticity of the brain at young ages, they are largely beneficial and pose no harm in their contribution to social and emotional development. This literature review expands the in-depth understanding of how and why early intervention plans, in particular, benefit cognitive and socio-emotional development, contributing to the knowledge base of early intervention research for people with Down Syndrome during the infant and childhood stages.

KEYWORDS: Behavioral and Social Sciences, Neuroscience, Down Syndrome, Cognitive and Socio-Emotional Development, Early intervention.

■ Introduction

Down Syndrome is characterized by challenges with respect to reciprocating someone's feelings, communicating what they think verbally and through body language, and more. Defined as an intellectual disability, it impacts cognitive, socio-emotional, behavioral, and physical development and traits. Phenotypic traits include distinctively flattened facial features and upward-slanting eyes,¹ while behavioral, socio-emotional, and cognitive differentiations include difficulties with maintaining attention, short- and long-term memory, social navigation skills, and executive function.² Down Syndrome is a developmental disorder caused by a genetic mutation - Trisomy 21, a biological phenomenon entailing a supernumerary chromosome 21. This occurs when an extra chromosome appears in the 21st autosome, which leads to certain differences in cognitive and socio-emotional development.³ This mutation leads to certain structural differences in the brain; neurons experience stunted dendritic growth, resulting in a smaller overall brain size, which is considered to play a significant role in cognitive and socio-emotional developmental difficulties. While the biological root cause of these difficulties cannot directly be addressed or cured in any way with current technology and scientific knowledge, early intervention plans target working directly on the hampered skills - for eg. social interaction - and have been known to have beneficial short and long-term benefits, of which improved intellectual and adaptive function (long-term) and higher IQ levels, though these tended to recede slightly with age (short-term) are some

of the most significant.⁴ These results are primarily the result of early intervention plans, as implementing programs alongside key developmental phases allows this development to be supported and guided at its most crucial and delicate stages. Research into the impacts of responsive teaching and model preschool programs displays considerable improvements in patients with Down Syndrome with respect to cognitive and socio-emotional developmental areas while addressing minor ethical risks, overall outlining the largely beneficial nature of early intervention plans and their valuable contribution to cognitive and socio-emotional development. This literature review analyses the structural differentiations in the brain and provides a baseline association with cognitive and socio-emotional development in Down Syndrome, highlighting the root cause of the underdevelopment of these traits. It then covers cognitive and socio-emotional development in Down Syndrome as a separate topic, establishes the connection between the two more strongly, and introduces responsive teaching and model preschool programs as successful early intervention plans, highlighting their advantages, disadvantages, and risks, and provides an overall view and details the reasons behind the outcomes of early intervention plans. It then evaluates the real-life implications of early intervention programs and how they longitudinally influence the well-being of Down Syndrome patients.

■ Discussion

Cognitive and socio-emotional development in patients with Down syndrome:

Cognitive and socio-emotional processes are crucial to effective thought and emotion control. Processes such as executive function (the lack, inhibition, or delay of executive function referred to as executive dysfunction) are found to undergo delayed or insufficient development in patients with Down Syndrome, leading to difficulties in social cognition skills and interpersonal communicative skills. Social understanding and engagement skills are central to intellectual development and a significant driver of overall development,⁵ especially during younger years at peak neuroplasticity levels when the brain is still forming and developing cognitive and socio-emotional structures and processes.⁶ Many children with IDs (intellectual disabilities) display a difference in rate of development of normal cognitive and socio-emotional abilities rather than a big difference in the development of the abilities themselves,⁷ and behaviors exhibiting typical social behaviors occurred at a lower frequency as compared to typically developing children - especially in self-reliant and competitive contexts.⁸

In Down Syndrome, on the other hand, there are multiple early indicators of emerging cognitive understanding that develop atypically, including dyadic interactions between the adult and the infant (mutual gaze, focal nature of gaze, reading of social signals, etc).⁵ Early dyadic interactions between infants and adults serve as a critical foundation for socio-cognitive development, interactions which are normally characterized by the infant's steadily growing receptiveness to subtle social and communicative signals.⁵ These interpersonal exchanges facilitate the transition to more complex interpersonal interactions within the first year of life, including the emergence of joint attention, intentional pointing, requesting behaviors, and imitative learning, wherein infants assume an increasingly leading role. This is instrumental in cultivating higher-order cognitive skills, most notably emotional recognition and theory of mind,⁵ which are essential for successful social navigation and interpersonal understanding,⁹ which are also, in turn, big factors of socio-emotional development through further years of childhood. Mutual gaze, an important marker of typical Early dyadic interaction, is slow to emerge in infants with Down Syndrome, but is then maintained at a high level in the middle of the first year,⁵ which is when it declines in typical development as the infant begins to pay more attention to the wider social and physical world, perhaps due to a need for more looking time to obtain the same amount of information or hypotonia. The 'focal nature' of the gaze of children with Down Syndrome entails a fixation on the parent's/caregiver's eyes rather than exploring other facial features, which could signify potential future implications in emotional recognition, leading to a significant hurdle in their ability to read critical social cues.⁵ The lack of the utmost foundational interpersonal skills compromises intellectual as well as overall development in the brain, as the knowledge garnered from social exploration is not gathered, and development in children with Down Syndrome builds onto already existing manifestations of executive dysfunction. This inhibition of development is mirrored

in structural differentiations visible in the anatomical development of the brain, affecting cognitive and socio-emotional development.

The structural differentiations in the brain associated with cognitive and socio-emotional development due to Down Syndrome:

The main basic structural difference exhibited in brains affected by Down Syndrome includes dendritic atrophy, which strongly affects cognitive and socio-emotional development.¹⁰ There are some set criteria against which the extent of dendritic atrophy is measured: the number of dendritic branches, the number of dendritic branch segments, and dendritic length and growth, the underdevelopment of which leads to cognitive impairment.¹¹

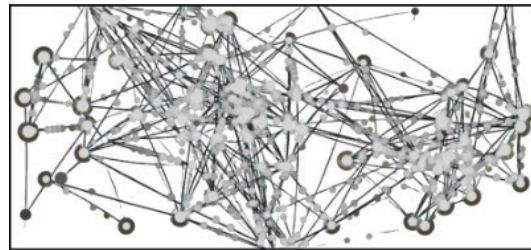


Figure 1: Representation of regular development of neural networks in neurotypical brains showing an approximation of dendritic branching and density.

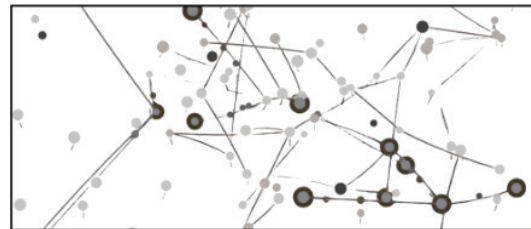


Figure 2: Representation of the development of neural networks in the brains with Down Syndrome, showing an approximation of dendritic branching and density as a result of dendritic atrophy.

The above diagrammatic representations, Figure 1 and Figure 2, demonstrate how brains impacted by Down Syndrome undergo dendritic atrophy, where the number of dendritic branches forming from the neurons reduces, and the frequency of growth decreases, leading to lower dendritic density and weaker neural connections. The neural networks formed in brains that are regularly developing demonstrate significantly higher levels of complexity, interconnectedness, and strength.

A study on the dendritic growth of brains impacted by Down Syndrome was conducted with a group of Down Syndrome patients and a control group ranging from infancy to early childhood stages.¹⁰ While the total number of dendritic branches was higher in infants affected by Down Syndrome, it quickly reduced in comparison to the control group. By around 5 years old, DS patients had a significantly lower total number of dendritic branches as compared to 5-year-olds in the control group, wherein the number had slightly increased with age. A similar effect was seen considering the number of dendritic branches - while infant Down syndrome patients displayed a high number of dendritic branch segments, they quickly fell with age, while unaffected children in the control

group experienced a quick increase in the number of dendritic branch segments.

Dendritic growth exhibited, again, similar tendencies - while there was a visible spurt in growth in the first four months of life, dendritic development significantly deteriorated after. In the control group, dendritic growth and expansion continued through early developmental stages and through childhood, the end age being unclear, but definitely continuing up to the age of five. Dendritic length, however, decreases from infancy itself in direct contrast to the control group, where dendritic length continues to increase as age increases. There is also often a lower number of neurons overall in Down Syndrome patients, the existing neurons solely exhibiting underdeveloped dendritic arborization - a characteristic of old age, earning the label of premature neuron aging. Abnormal dendritic length of the spines and underdeveloped dendritic arborescence are particularly identified in cortical pyramidal neurons, crucial to cognitive functioning.¹¹ This significantly hinders neuron connection, and the consequent reduction in synaptic density significantly hinders neuron connection, and negatively affects the brain's ability to form proper neural networks. These structural changes in the brain circuitry affect the processing and transmission of information and brain plasticity, including the ability to form new connections and the capacity for learning and adaptation. Due to its nature, the cognitive gaps grow along with patients, and cognitive learning slows down, undergoing a 'progressive postnatal degenerative process'.¹¹

Other structural abnormalities include an immature gyral pattern,¹² which inhibits neural processing;¹³ irregular neo-cortical laminar formation,¹⁴ essential for higher cognitive function; and delayed myelination of cortical fibers,¹⁵ the neural pathways in the cerebral cortex responsible for a multitude of cognitive and sensory functions.¹⁶ While these changes are hard to control or slow down after a certain age, intervention plans targeted at slowing down or stabilizing cognitive and socio-emotional degeneration at an early, developmental stage have a significant positive impact on people with Down Syndrome's lives.

Early Intervention plans aimed at improving cognitive and socio-emotional development:

Early intervention plans have higher success rates as compared to therapies conducted for older individuals with Down Syndrome,¹⁷ as they take advantage of the high neuroplasticity of infant brains, intervening during periods of crucial, foundational, cognitive and socio-emotional (as well as overall) development.¹⁸ Responsive Teaching, or RT, is one example of an early intervention plan. The program trains parents/caretakers of the patient on how to navigate interpersonal interactions with the patient to facilitate optimum developmental progress with more ease. The introduction of responsive interaction strategies into everyday correspondence encourages active engagement and learning processes, supporting more beneficial socio-emotional and cognitive development. There are 5 responsive interaction strategies. Reciprocity (using mirroring to join in an activity, being physically available and interactive, sustaining repetitive play, and maintaining face to face play

void of external distractions such as toys), Contingency (taking the child's perspective, rapid identification and response to non-verbal requests, translating the patients actions into words, acknowledging unintentional vocalisations), Shared control (communicating without asking questions, imitating the patient's actions, giving the patient frequent opportunities to make independent choices, waiting for more mature responses rather than accepting every immature response from the patient), Affect (being animated, accompanying verbal communication with non-verbal communication, talking about novel or valuable actions of the patient), and Match (adjusting requests and interactions to the patient's unique developmental level). In a study conducted throughout the duration of a year, with 50 children with Down Syndrome and other similar developmental disorders, the developmental rate was proven to increase significantly with large jumps in the patients' capacities for expressive and receptive language.¹⁹ Specifically, there was a 64% increase in cognitive development, 167% increase in expressive language, and 138% increase in receptive language, resulting in a 123% overall increase in developmental rate.

Another example of an early intervention plan is an early intervention preschool program. One empirical study investigating the early intervention focused on 4 key developmental areas in infants with Down Syndrome - Gross motor development, Fine motor development, Socio-emotional development, and cognitive and language development. The intervention plan implemented activities that encouraged movements such as turning, crawling, sitting, and walking, tailored to each infant's unique capabilities and progress, to support gross motor development. Activities centered around hand-eye coordination and manipulation skills were implemented to strengthen fine motor development. Instruction supported family activities and parent/caretaker involvement in aid of social and emotional development, and encouragement of communication through activities such as singing, finger games, and responsive talking was implemented to support cognitive and language development. Another study targeted and evaluated six key skill areas - gross and fine motor, cognition, receptive and expressive communication, and social self-help. Similar to the first study, parent involvement and instruction in all areas of instruction played a critical role in supporting the development of the children. Both studies display significant improvements in overall development. Hines and Bennett's study employed the Gesell Infant Development Scale (which assesses development in four areas - motor, adaptive, language, and personal-social skills) and assessed the infants with Down Syndrome at 4 - 6 months, at one year, and then at regular annual intervals. Tracking gross and fine motor skills, cognitive and language abilities, adaptive and interpersonal behavior, DQ (developmental quotient) of participants of the intervention plan were proven to remain stable, contrary to the trademark decrease in cognitive and socio-emotional abilities usually seen in patients of Down Syndrome, and directly in contradiction to the biological development of Down Syndromic brains.⁴ Fewell and Oelwein's study assessed the DQ of its participants as well, but through calculation of the IR (Intervention Rate, the rate of develop-

ment during the program) and the DRP (Developmental Rate Pretest - the rate of development observed throughout the initial years of the infant before implementation of the intervention plan) in proportion, factors which were calculated with respect to the average change of cognitive and socio-emotional development per month. Measured in percentages, the DRPs across the six developmental areas ranged from 0.58 to 0.68, while the IRs displayed significant increases ranging from 0.92 to 1.23. Cognitive development displayed an increase of 0.55, and developmental areas concerning socio-emotional development, such as receptive and expressive communication and social self-help (all of which constitute social awareness and interpersonal interactions), showed increases of 0.48, 0.56, and 0.43, respectively.²⁰

The results of these studies show a largely positive, long-term effect on cognitive and socio-emotional development. Responsive Teaching tracked over a year demonstrates significant increases in the developmental rate of cognitive abilities and socio-emotional skills. The Early Intervention Preschool Program proves strong short-term improvements in important cognitive abilities, and socio-emotional abilities such as social awareness, interpersonal interactions, as well as a stable increase in the rate of long-term development in the initial years following the Early Intervention program. While these interventions considerably improve the quality of life for children with Down Syndrome by improving cognitive and socio-emotional development and therefore supporting a successful personal and social life, young adults with Down Syndrome characterize 'well-being' after rehabilitation largely as success in four domains of their lives - Relationships, Community participation, Independence, and Hopes for the future.²¹ Improvement in skills such as receptive and expressive communication indicates an increase in the patient's interpersonal skills, and consequently their capacity to successfully navigate Relationships. This, as well as a marked improvement in social self-help, contributes to ease in community participation and independence, and an improvement in motor skills and cognitive development supports all four domains of a 'good life'. In this manner, the early intervention programs discussed, Responsive Teaching and the Early Intervention preschool program, significantly contribute to the well-being of Down Syndrome patients through childhood and young adulthood.

■ Conclusion

This literature review posits that early intervention plans have beneficial results towards improving cognitive and socio-emotional development prospects for people with Down Syndrome due to its congenital nature. Down syndrome is caused by Trisomy 21, a genetic mutation,³ and can be characterized by trademark symptoms of dendritic atrophy, which correlates with cognitive and socio-emotional development rates slowing down as Down Syndrome progresses. Cognitive and socio-emotional rate of development is significantly lower in children with DS, and usually stagnates after 6-10 years of age.^{10,18} This is supported by the structural differentiations observed, mainly the dendritic atrophy and the smaller shape of the brain.^{10,11,13} Early intervention programs, such as pre-

school programs and responsive teaching, target maintaining or improving cognitive and socio-emotional developmental rates through targeting the symptoms, including interpersonal interactions, social engagement, and awareness, etc., and are effective in increasing the rate and the peak levels of cognitive and socio-emotional development.^{4,8,17-20} Longitudinal research on early intervention programs is not available in large quantities, and therefore, this domain requires more extensive research to be done to more reliably gauge the general effectiveness of early intervention programs through childhood and adulthood, across children with Down Syndrome across the spectrum of severity. Structural abnormalities associated with Down Syndrome pose a considerable opportunity to learn more about the developmental barriers and causes of the atypical development but are not explored in depth past dendritic atrophy and a basic understanding of the visually atypical elements of the brain; an aspect that therefore demands to be researched more in-depth to investigate its role in socio-emotional and cognitive development more thoroughly, and gradually lead to a sure command of the causes of Down Syndrome and effective early intervention plans. Research on social cognition is another vast gap in research about DS, due to an inaccurate perception that children with Down Syndrome have high socio-cognitive abilities due to high levels of sociability, which is not and should not be considered a true indicator of the necessary socio-cognitive abilities required to maintain a healthy, social life, and longitudinal and bidirectional relationships.⁵ Therefore, future research should focus on socio-cognitive challenges that people with Down Syndrome face, particularly emotional recognition and Theory of Mind.

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