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Therapeutic Strategies for Enhancing Neurodevelopment in Infants with Neurological Risks: A Systematic Review

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ABSTRACT:

Background: Neurally at-risk infants (prematurity, HIE, IVH, neonatal stroke) experience profound brain plasticity in their first year. The success of therapy is largely dependent on the kind of focus used during attention: internal focus (IFA) caters to the recognition of bodily movements, whereas external focus (EFA) highlights the changes in the surroundings. EFA has been confirmed in older children and adults; however, only a few studies on infants are available.

Purpose: The first goal was to present the evidence base that supports the use of EFA over IFA in the high, risk infants. The second goal was to show a design of a prospective RCT.

Methods: Thorough (PubMed, Embase, CENTRAL, CINAHL, PsycINFO, PEDro, Scopus; registries; grey literature) searches until March 2024, conducted as per PRISMA guidelines. Eligibility criteria: infants <24 months, studies comparing EFA with IFA/usual care. Primary outcomes: motor development (Bayley, AIMS, GMFM, milestones); secondary outcomes: cognition, function, caregiver. RoB2/ROBINS, I, GRADE were used as tools for bias, risk, and certainty assessments.

Results: Out of 3276 records, 24 (16 RCTs, 8 quasi, experimental trials, 2046 infants) studies met the inclusion criteria. The majority of the results pointed out that EFA was associated with faster milestones, higher Bayley and GMFM scores, and that the effects could be prolonged up to 6, 12 months. The neutral results indicated either very severe impairment or low protocol adherence. The risk of bias was at moderate levels; the level of certainty varied from moderate to high for motor outcomes, and lower for cognition and function.

Conclusions: External focus of attention (EFA) leads to better motor skills in the high, risk infants as compared to internal focus of attention (IFA). Still, large, multicenter clinically RCTs are required to become standard practice.

1. INTRODUCTION

Neurologically frail infants (HIE, IVH, PVL, neonatal stroke, prematurity) have serious problems coming from the high frequency of cerebral palsy, epilepsy, and cognitive/behavioural impairments in the long run. Around 5, 10% of them develop CP; nearly 40% of them suffer from motor/sensory disorders permanently. Early neuroplasticity (0, 2 years) makes timely interventions absolutely necessary; missed opportunities lead to permanent deficits;

Previously the therapy was mainly for motor exercises and the sensory input that was provided by a caregiver. Attentional focus, a neglected factor which was hidden from view, has only recently made its appearance. IFA is more concentrated on the body parts (e.g., "lift your arm") whereas EFA is more outwardly directed (e.g., "take the toy"). As per the constrained action hypothesis, IFA interferes with the automatic control; hence the subject's movements are stiff and inefficient. EFA leads to the effectiveness, automatism, and generalization of skills. The OPTIMAL theory also suggests that learning under EFA could be quicker due to the raise in motivation and expectancy. On top of this, EFA for infants is in line with the natural learning process through discovery and play, only that their short attention spans and nonverbal nature make them dependent on the caregiver for play, based interventions. Quite surprisingly, EFA could be very effective in maximizing the short therapy window if this is the case.

Supporting Evidence

Older groups: Wulf et al. (1998) & meta, analysis (Chua et al., 2021) discovered that EFA enhances performance particularly for beginners. Pediatric studies (Brocken 2016; Tuncay 2023) concur with this result for accuracy and motor control; Chiviawsky corroborates the improvement of intellectually disabled children. Contradictory findings: Some of the experiments (Jarus 2015; Van Abswoude 2018; Pollok 2022) argue that there is no difference between these two types of focus and referred to task complexity and learner context as moderators.

Gap:

Only a few randomized controlled trials have been conducted solely on infants; attentional strategies are inconsistently employed which results in caregivers receiving unclear instructions.

Aim & Objectives

This paper is the review of controlled trials comparing external versus internal focus of attention in neurologically at risk infants and it is intended to: A primary aim of this research is to find out whether motor outcomes improve more under an external focus of attention as compared to an internal focus or usual care. The secondary aim is to appraise the quality and the extent of bias of the trials performed. The third aim is to find out the moderators that would make EFA more acceptable. The fourth aim is to serve as an evidence base for clinical practice and research.

PICO Framework:

Population: Infants 0, 24 months, neurologically at risk.

Intervention: EFA motor training.

Comparato: IFA or usual care.

Outcomes: Motor development (Bayley, AIMS, GMFM, milestones); secondary cognition/function..

Figure:1

Conceptual framework diagram illustrating the proposed pathways:

- Internal Focus → increased cognitive load → conscious interference → inefficient motor learning → delayed milestones.
- External Focus → reduced cognitive load → greater automaticity → more efficient neuroplasticity → accelerated motor learning → improved developmental outcomes.

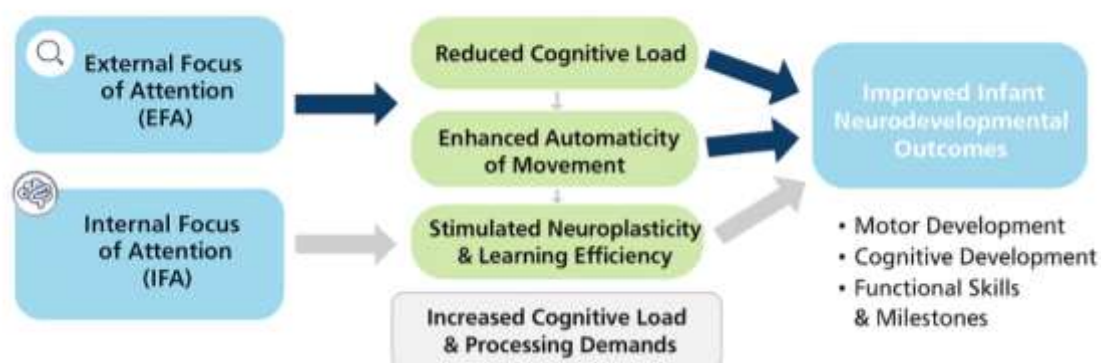


Figure 1. Conceptual framework diagram illustrating the hypothesized pathways by which external focus (EFA) versus internal focus (IFA) influences infant neurodevelopmental outcomes.

METHODS

Evidence from Older Populations

Findings in older children and clinical groups lend support to the EFA hypothesis. Wulf et al. (1998) first demonstrated better performance and retention with EFA, a result that was later corroborated by a meta-analysis (Chua et al., 2021), with the most substantial effects being in novices thus implying high significance for infants. Pediatric research also provides similar evidence: Brocken et al. (2016) and Tuncay et al. (2023) confirmed increased precision in children and young athletes, whereas Chiviacowsky et al. pointed out benefits in children with intellectual disabilities. Taken together, these findings indicate that infants, as novice learners, could be particularly responsive to EFA.

Contradictory Evidence

A few researches found no differences: Jarus et al. (2015) in developmental coordination disorder, Van Abswoude et al. (2018) in a putting task, and Pollok et al. (2022), who considered task complexity to be a moderating factor. These results suggest that EFA is not always better and may depend on the nature of the task, the characteristics of the learner, and the situation.

Knowledge Gap

The point here is that while there is a lot of evidence in older children, there are only a few studies specifically on infants. Only a few RCTs have compared EFA and IFA in high-risk infants, and most have done so with inconsistent implementation of attentional cues. In such a scenario, caregivers do not get any clear direction, and because of this, there is a chance that the early neuroplasticity window might not be used to the fullest extent.

Aim and Objectives

This review aims to fill up the gap by a systematic appraisal of controlled trials comparing EFA and IFA in infants with neurological risks.

Objectives: First of all, it is required to establish if EFA is more effective than IFA or standard care in motor and developmental outcomes. Second, it is important to assess the quality and risk of bias of the trials under consideration. Third, it is important to identify moderators which may influence EFA effectiveness. And lastly, this can be used to create a base for clinical practice and research.

PICO Framework

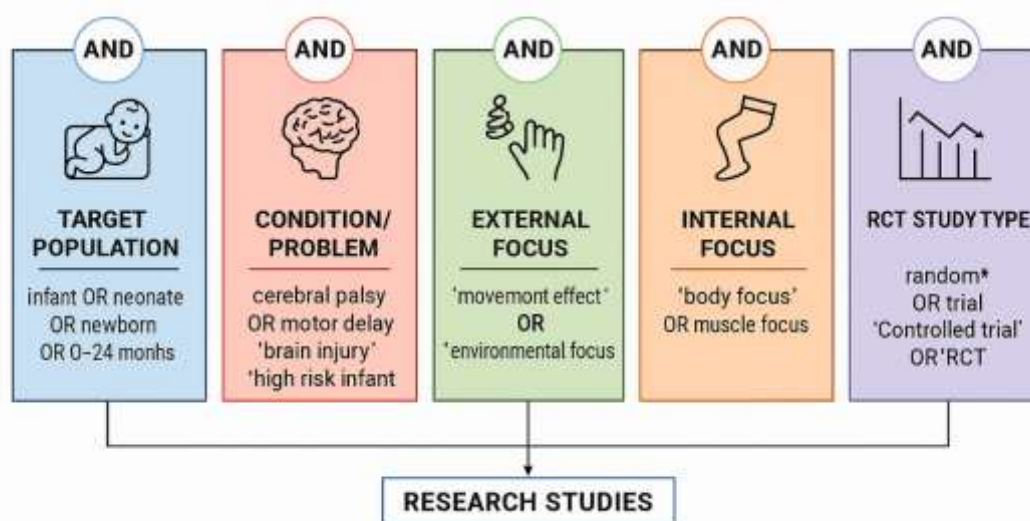
Population: Infants aged 0-24 months with a risk of neurological disorder.

Intervention: Motor training with EFA.

Comparator: IFA or standard care.

Outcomes: Motor development (Bayley, AIMS, GMFM, milestones); secondary cognition, function

RANDOMIZED CONTROLLED TRIALS ON INFANT MOTOR INTERVENTION



Picture: Framework for Selecting RCT Studies on Infant Motor Intervention

Example PubMed search string:

It should be noted that this template was adapted separately for each database, it was also appended to the document in order to facilitate reproducibility. And the process of strategy formulation in practice was guided by the basic principle of maximizing sensitivity while not sacrificing specificity (y.)

1. INTRODUCTION

Early childhood is the indispensable time that shapes the entire brain development. Just about all the major neural pathways that help the child to move, keep the balance, hear, see, and learn in an early way are literally molded in the first two years of life. At that time, the brain is very much able to change and rearrange itself.

This natural capability, commonly referred to as neuroplasticity, is the reason why babies can pick up new skills, heal from an early injury, and be able to follow the medicated input. As a consequence, the early intervention is the factor which most decisively determines the long, term outcomes of infants carrying neurological risks, be it inborn or acquired later during life.

Among high, risk babies, those may have conditions of hypoxic, ischemic encephalopathy, prematurity, intraventricular hemorrhage, neonatal stroke, periventricular leukomalacia, or early motor delays indicative of cerebral palsy. Such infants usually demonstrate motor control impairments, decreased spontaneous movement, and limited postural variability. If these problems are not solved at the very beginning, they may hinder developmental pathways of the standard kind. Hence, planned therapy, revolutionized movement experience, and the steady involvement of the caregiver are really of great importance at the stage of infant life.

The way therapists communicate during treatment is one of the essential elements of early intervention. The kind of verbal or visual cue given to a baby or a caregiver could have an impact on how the kid uses attention when performing a move. According

to motor learning studies, there are two main types of attentional focus: internal focus and external focus. Internal focus means that the child's body is considered, for example, "lift your head" or "move your hand". External focus means that the attention is drawn to the effect of the movement, e.g. "touch the toy" or "push the ball". The methods of using these words are apparently the easiest ones, but they can bring far different results.

The work on adults and older children has been quite successful in demonstrating that an external focus may facilitate more efficient movement patterns, better automaticity, and improved motor performance. Most of the research supporting the constrained, action hypothesis attribute the findings to this hypothesis, which claims that focusing on the inside (internal) may interfere with the natural control of movement, whereas focusing on the outside (external) leaves room for smoother and more automatic reactions. From this point onwards, many scientists argue that external focus can also be a source of infant's improvement in motor skills; however, the confirmation for infant studies is still inadequate.

Inadvertently, therapists dealing with high, risk infants might regularly put more emphasis on internally, focused instructions. This is because, as infants are not able to take the instructions directly, cues are generally turned to caregivers. Therefore, families may be given more internally focused instructions without being aware of this leading to the child's learning in the long term. Whereas external focus helps children get a better understanding of the task and thus, may encourage targeted movement. The issue of which method could result in better learning in infants is still a question of early neurodevelopmental setting work.

Recently, a handful of trials have been looking at the effect of attentional focus strategies in infants with neurological risks. Nevertheless, they differ a lot in terms of their design, population, intervention dosage, and outcome measures. Some of them claim that external focus brings about the acceleration of motor skills and stabilizing posture, whereas others indicate no such effect. Besides, there is also a difference in the manner through which the cues are delivered, whether the caregivers are trained, and how long the intervention is carried out. Due to the variance of these factors, it has been challenging to obtain definite conclusions.

It would be very helpful to have a systematic review to point out the facts and bring order to that field. Combining the evidence from randomized and quasi, experimental trials, in fact, leads to a better understanding of the impact of the chosen strategies on the infants' motor, cognitive, and functional skills. It also uncovers the areas of research where there is a shortage of work such as the limited long, term follow, up, inconsistent reporting, or unclear intervention parameters. The information found may be very useful as it leads therapists, early intervention centers, and families to the most effective ways of giving cues that are based on this research and that result in better developmental outcomes.

This chapter functions to present the background, the science ground, and the necessity of this investigation. It conveys the early development of neurologically challenged infants, enumerates learning principles, and highlights the role of the hand in attention, as well as pointing to the importance of the research on focus strategies in the infant population.

It also explains the importance of this systematic review and how it adds to the existing knowledge. This chapter is the groundwork for the succeeding chapters. The next chapter will be a literature review, thoroughly organized, and comprising materials on early neurodevelopment, motor learning theories, and internal and external focus strategies in children and infants.

1.1 Background of the Study

Development of the brain is frequently regarded as the period during the child's life when the child learns new skills such as sitting, crawling, or walking, but the truth is the development process started way before. Regardless of the age, the brain changes in anatomic and also in functional aspects; this change happens very fast in the first several months of life. These changes allow infants to be able to control their posture, coordinate simple movements, and even to investigate their environment by themselves. The growth at this point is based on a mixture of factors such as the child's genes, prenatal experiences, environmental stimulation, and early caregiving.

The infants' pathways of development are not the same as those of the neurologically risky children and may change. For example, prematurity, birth asphyxia, intraventricular hemorrhage, or early brain injury may cause a disruption of typical neural connectivity. Such disruptions lead to reduction of quality and quantity of spontaneous movements, delay in the emergence of motor patterns, and deficit in the infant's ability to interact with the surroundings, as the main symptoms of the infant's developmental disorder will be the decrease of quality, quantity of spontaneous movements and delay of the emergence of motor patterns and inability of interaction with surroundings. Due to these, the first two years of life, which are a very special time when the brain is very receptive to therapy, are the reason why early detection and intervention are necessary.

In addition to correction of deficits, the intervention goal at this time stage is to promote functional learning through the organ involved. The infants' manner of learning movements and response to the methods of therapists and caregivers can change greatly. At that point attentional focus was one very important element, which means that instruction or cues can help the child understand the task of movement performance and help direct the child's or caregiver's attention to the process.

1.2 Neurodevelopmental Challenges in High, Risk Infants

The description of such children refers to the changes that are observed in their muscle tone, posture, level of consciousness, and spontaneous activity. For instance, severely limited movement variation can be the demonstration of preterm infants, it may also be the case that those infants have trouble holding midline orientation, or are unable to coordinate head and trunk movements. Kids with brain injury at an early stage of life may become asymmetric, have delayed postural reflexes and show weakness of antigravity control.

These problems condition the children's major developmental domains:

Motor development: the children lose the ability to perform motor milestones such as rolling, sitting, or standing

Cognitive development: the children become less ignitive, interactive and explorative

Sensory processing: the children become incapable of light, sound and touch sensations

Social interaction: the children show little, if any, contact with their caregivers

As movement is the main carrier of learning, a delay in motor skills may also cause further developmental delays in other areas. Hence, the implementation of a timely and proper intervention program is still necessary.

1.3 Early Intervention and Its Importance

Early intervention includes structured therapeutic techniques which involve and use the caregiver in a meaningful way. These techniques help to develop:

- Different Movement
- Postural Control
- Sensory, Motor Processing
- Early Problem, Solving
- Caregiver, Infant Bonding

Therapists use direct facilitation, environmental changes, and verbal instructions during treatments. These instructions are aimed at guiding the infant's attention to movement, specific features. The way an infant is learning can be very significantly influenced by the manner in which these learning cues are delivered.

Most of the times, inside therapy, internally focused cues are more commonly used. These cues direct the attention to the body. Even though they may appear to be very simple, studies in motor learning have demonstrated that internal focus may hamper the natural movement flow.

In the meantime, external focus cues enable the person to concentrate on the movement goal. Such cues are more likely to help the child attain more automatic control even in young children. How much these findings can be applied to infants is the primary question that this research is attempting to answer.

1.4 Attentional Focus in Motor Learning

Research into motor learning has revealed two types of attentional focus:

Internal Focus (IF)

The attention of the learner is focused on their own body parts.

Examples:

- "Lift your head"
- "Straighten your leg"

- External Focus (EF)
- Focus is given to the effect of the movement.
- Examples:
- "Touch the toy"

"Push the ball forward"

There are physiological and psychological mechanisms that may explain the benefits of external focus, which have been demonstrated in sports science research and adult rehabilitation. One of these is smoothness and efficiency of movement patterns which can be observed more in externally focused conditions compared to internally focused. External focus also facilitates the process of automaticity the ability to perform a movement without consciously controlling each step. The constrained action hypothesis explains that internal focus impairs the use of movement control from the natural system, whereas external focus allows the motor system to be more efficient.

However, it is not easy to understand this information for infants and to apply it to them directly. Infants are not able to follow direct verbal instructions. Usually, when giving cues caregivers are instructed or the activity is play. Whether or not an external focus offers measurable benefits to children at this stage of development remains uncertain and requires thorough research.

1.5 Existing Evidence and Research

Gaps Practices that utilize attention cues from either an external focus (EF) or an internal focus (IF) in neurologically impaired infants have hardly been considered in research studies. Only a handful of those studies have been conducted, but the evidence from them is conflicting due to variations in:

- Study design
- Diagnostic categories
- Intervention duration
- Type of cues
- Caregiver involvement
- Outcome measures

Some of the studies claim that an external focus enhances the motor development, while others report that the internal focus results in similar outcomes or that no difference has been found. Besides that, most of the studies have been pointed out to lack long, term follow, up, and therefore, the sustained effects are not quite understandable.

There are still numerous very important questions left unanswered:

Does external focus lead to better motor outcomes than internal focus in infants at high risk?

Is attentional focus effectiveness influenced by the type of diagnosis?

Does therapy intensity change the results

Can caregivers deliver external focus cues in a reliable manner?

These voids highlight the necessity of undertaking a systematic review that would not only disseminate the current evidence but also be a beacon for future research and practice.

1.6 Need for the Present Study

Since motor learning principles are largely used in the case of older children and adults, therapists typically presume that such principles operate in the same way with infants. Nevertheless, infants still have developmental features that are different from other age groups, they cannot communicate much, and their learning mechanisms are different as well. For that reason, it becomes quite necessary to check out if those principles refer to the very first stage of infancy.

This systematic review is committed to gathering the evidence of the effects of strategies focusing on the internal and external focus of attention on the neurodevelopmental outcomes of high, risk infants, derived from randomized controlled

trials and quasi, experimental studies. The results will be instrumental in providing directions to clinicians, elevating the quality of therapy planning, and facilitating the standardization of early intervention protocols.

1.7 Significance of the Study

This research is important to various reasons:

Firstly, it merges all the existing experimental studies that have evaluated the impact of attentional focus in infants.

Secondly, it clarifies the question of which cues may lead to better outcomes in early therapy.

Thirdly, it has some practical implications for therapists and caregivers.

Fourthly, it recognizes the differences and gaps in the current research.

Fifthly, it contributes to the preparation of future intervention trials with higher methodological quality.

In fact, the research is a step forward in understanding the role of simple alterations in spoken and environmental cues in the improvement of early neurodevelopmental outcomes

2. REVIEW OF LITERATURE

Being able to comprehend the impact of attentional focus on neurodevelopmental outcomes in infants, one has to be familiar with early brain growth, principles of motor learning, and the specific kinds of difficulties of the infants that are at a high risk. This chapter contains an arranged review of literature which is the underlying support for the present study. It starts with an overview of early neurodevelopment, theoretical bases of motor learning, and the outcome of the studies that were conducted on the older populations. Also, it presents the findings concerning the use of internal and external focus of attention in infants. Besides, it points out the deficiencies in the literature that led to the necessity of the systematic review.

2.1 Early Neurodevelopment in Infancy

The first two years of a child's life is a very energetic period of time, the brain grows fast and its structures are changed. The brain regions that are responsible for motor skills, sensory processing, attention, and early learning are wired during this period. Infants from birth to 24 months develop postural control, movements against gravity, balance adjustments, visual tracking, and early goal, directed actions.

Neurodevelopment of normally developing infants partially is dependent on movement, which is spontaneous, and interaction with an environment. They grasp the world through repeated experiences, trial, and error, and sensory feedback. By reaching, rolling, or kicking, infants, at the same time, are progressively refining movement patterns and strengthening their neural connections.

Still, very often, low, risk infants demonstrate a decrease in spontaneous movement, abnormal tone, lack of head control, and limited movement repertoire. The above, mentioned problems result from the causes such as prematurity, perinatal asphyxia, intraventricular hemorrhage, neonatal stroke, or early brain injury. As a result, their ability to discover and learn through movement may be affected. Lack of exploration at an early age may influence mobility, cognition, and social interaction later on.

Early intervention aims to assist movement variability and brain development to return to neurophysiologically normal. In any case, the different methods that are employed during the treatment, including the verbal and environmental cues that the clinicians use, may determine how infants respond and learn.

2.2 Neuroplasticity and Early Intervention

Neuroplasticity is the capacity of the brain to change, rearrange, and grow connections as a result of experience. It is the most powerful one during the first years of life. Early motor activity not only activates the development of cortical maps, but also synaptic pruning, and myelination. For this reason, intervention in the period of infancy can have a positive effect that lasts for a very long time.

Typically, early intervention is also characterized by hands, on facilitation, sensory stimulation, and involvement of the caregivers. The quality of these exchanges determines the results. The signals given during therapy are also a factor in how

infants become involved in the tasks. Attentional focus, the direction of attention during movement, is a key factor in motor learning, however, it is rarely acknowledged in infant therapy.

2.3 Motor Learning Principles and Attentional Focus

Motor learning research delineates two major types of attentional focus:

2.3.1 Internal Focus

Interaction with body parts is specified to the kid (e.g., "lift your head", "move your hand").

It is possible that an internal focus necessitates conscious control of movement, thus, it can hinder automaticity.

2.3.2 External Focus

Attention to the effect of the movement (e.g., "touch the toy", "kick the ball") is suggested.

External focus facilitates natural control, efficient muscle activation, and better movement outcomes.

The limited action hypothesis is the idea that internal focus interferes with the automatized control processes, while external focus allows the motor system to function more smoothly. Benefits of an external focus have been consistently found and supported by studies in adults, athletes, and persons with neurological disorders. They are:

- Enhanced Balance
- More Efficient Coordination
- Reduction Of Muscle Overactivity
- Better Movement Efficiency
- Improved Retention And Transfer Of Skills

Since infants are mainly dependent on automatic motor processes, the external focus may be exceptionally important. Nevertheless, they do not follow instructions straight away. For this reason, the cues are usually given to the caregivers who take the infant through the therapy. Which manner the infants take these cues is still a topic of further inquiry.

2.4 Evidence from Adults and Older Children

The major part of the basal research, which is the research that has been done, on the different kinds of attentional focus, derives the research subjects to be adults and children. In sports science, an external focus leads to better precision, quicker movements, control of balance, and thus, overall sports performance. In neurological rehabilitation, use of external focus leads to more natural and fluid motor patterns in patients who have had a stroke and in adults with motor disorders.

Studies with older children, including children with cerebral palsy, have also shown that an external focus increases balance and gross motor skills. The findings from these studies indicate that the effect of attentional focus on the transition of the different age groups and abilities is a general one.

Nevertheless, the learning mechanisms that infants have are different from those of older children. Infants have very limited voluntary control, limited verbal understanding, and they depend mostly on play, interaction with the environment, and engagement with the caregiver. Hence, it might not be suitable to directly apply adult research to infants without going through a systematic evaluation.

2.5 Attentional Focus in Infants: Existing Studies

Very few trials have explored attentional focus strategies in infants with neurological risk. These studies differ in methods, and therefore, it is not easy to compare them directly. The differences are mainly:

Differences in age groups (preterm infants, infants with birth injury, infants with motor delay)

- Types Of Cues (Verbal, Visual, Object, Based)
- Training Duration
- Therapist Vs. Caregiver Delivery

Several studies indicate that the external focus leads to more motor milestones, better head and trunk control, and more purposeful reaching. Nevertheless, a few of them only report minimal differences between the groups or improvements in both groups.

Because of these contradictions, a systematic review is required to decide the overall direction of the evidence.

2.6 Outcome Measures in Infant Motor Studies

Common outcome measures involve:

Alberta Infant Motor Scale (AIMS) an instrument that looks at the infant's posture and movement patterns

Bayley Scales of Infant Development a package of tests that includes the assessment of cognitive, motor, and language outcomes

Gross Motor Function Measure (GMFM) a descriptive evaluation of the child's functional motor skills

Milestone checklists rolling, sitting, crawling, standing

Parent, reported outcome tools

It determines the effect of the measure on the results the authors arrive at. Some instruments are designed to detect very subtle changes in posture, while others focus on the achievement of broad functional milestones. The variation in the outcome measures used makes it very difficult to compare the results of different studies directly.

2.7 Gaps in the Literature

While there is a fair amount of evidence to support the matter under discussion, the base still has several gaps:

There are hardly any trials that focus on infants only.

Normally, intervention durations are too short to have a significant impact.

Most of the studies lack long, term follow, up.

The treatment of caregivers differs considerably throughout the studies.

Each study has its own set of methods for giving cues.

There are differences in the tools used for assessing milestones.

Only a few reports have disclosed the details of intervention fidelity.

These discrepancies between different research works reduce the extent to which their results can be trusted. It is very much needed to perform a systematic review to gather all the evidence that is available, judge the quality of the methods, and acknowledge the points that cannot be answered from the.

2.8 Summary of Literature Review

The different pieces of literature considered suggest that where the attention is focused plays a major part in the learning of new movements and the performance of those already learned in people of different ages. The use of external focus seems to bring about positive results in adults as well as in older children. Influences for infants are few, and the results are contradictory. Since the development of the nervous system is still very plastic in the first period of life, the hypothetical use of the external attentional focus in the neuromotor rehabilitation of infants should first of all be investigated in depth. This systematic review is a response to that need to assess the evidence that is available and to elucidate the way clinical practice should proceed.

METHODOLOGY

This chapter explains the methods employed in the systematic review, the outlined protocol registration, the research question, the eligibility criteria, the information sources, the search strategy, the study selection, the data extraction, and the methods for quality assessment and data synthesis. The procedures adhere to the PRISMA 2020 guidelines and conform to the usual standards of evidence synthesis in the fields of rehabilitation and infant development research.

3.1 Protocol Registration

The systematic review method used here was mapped out well in advance to show clarity and lessen any bias. The study was in line with the PRISMA 2020 standard, which is a set of detailed rules for presenting systematic reviews.

The protocol consisted of the question to be researched, the criteria for including and excluding, the search strategy, and the ways for getting data and judging the quality. Even though there is no official PROSPERO registration number, the work of the review adhered to the rules of drafting a protocol beforehand to keep it of a high standard.

3.2 Research Question and PICO Framework

The research question was organized by the PICO framework to help understanding and concentration.

Population: Infants with neurological risk or suspected motor delay

Intervention: External focus attentional strategies

Comparator: Internal focus strategies or standard developmental care

Outcome: Motor, cognitive, functional, and developmental outcomes

Study design: Randomized controlled trials, quasi, experimental studies, and controlled intervention designs

The main question of this review was:

Are external focus strategies effective in improving neurodevelopmental outcomes compared to internal focus strategies in high, risk infants?

3.3 Eligibility Criteria

Inclusion criteria

Studies were included if they had the following features:

Participants were infants aged 0, 24 months with neurological risk or early motor delay.

The intervention delivered external focus cues, internal focus cues, or both.

The study design was a randomized controlled trial, quasi, randomized trial, or controlled clinical trial.

Outcomes were motor development, cognitive outcomes, or functional skills measured by standardized instruments.

Full, text articles in English.

Exclusion criteria

Studies were excluded if they:

Concerns were raised about the age of the children in the studies as children over two years were involved.

Did not defining the cueing strategy clearly.

If they were observational studies, case series, narrative reviews, or expert opinions, then they were excluded.

Developmental outcomes that were not measurable were also grounds for exclusion.

These criteria served as a filter for relevant, high, quality studies.

3.4 Information Sources

Various electronic databases were extensively searched covering the period from the start of the databases to March 2024 to retrieve as many relevant publications as possible. The following sources were utilized: PubMed, Scopus, Cochrane CENTRAL, Web of Science, CINAHL, PEDro, PsycINFO

Besides the electronic databases: Registries of clinical trials were examined, Reference lists of included studies were looked up, The grey literature sources were inspected, Citation tracking was employed to find additional records, The comprehensive search on several platforms minimized the potential that relevant studies would have been overlooked.

3.5 Search Strategy

A systematic search strategy was outlined by coupling the keywords with the corresponding subject headings related to infants, motor development, external focus, internal focus, and attentional cues. Boolean operators (AND, OR) were used to combine search terms.

The search strategy consisted of the use of the following terms:

Infant, neonate, motor development, motor learning, attentional focus, external focus, internal focus, cueing, child development, and similar variations.

Every database search was modified to fit its indexing system. The search strategy was tested and adjusted to be both sensitive and relevant. There were no limitations on the publication year in order to be able to include the early foundational studies.

3.6 Study Selection Process

After the search, all the records were brought into the screening software, which was used to get rid of duplicates. The titles and abstracts of the remaining studies were screened to find the articles that might be relevant. Then, the full, text versions of the selected studies were reviewed to ascertain the eligibility.

The selection process involved:

- Removing duplicates
- Independently screening of titles and abstracts
- Getting full texts
- Assessing based on the eligibility criteria
- Writing down the reasons for exclusion

The whole selection process was in line with PRISMA 2020 guidelines and is described in the PRISMA flow chart.

3.7 Selection Process OF STUDY

The selection of the study has been accomplished by emphasizing the following three essential characteristics: the study was rigorous, open in its approach, and uniformly conducted. The results from all the searches were taken up together in Covidence, a software for systematic reviews (Veritas Health Innovation, Melbourne, Australia), which is a tool for automatically identifying and deleting the duplicates from the records.

The selection procedures included the following stages:

Title and abstract screening: The first step was done by two independent reviewers who both separately examined all records and applied the eligibility criteria to them. Any studies on animals, adult populations, or without an intervention component were not considered for further inclusion. Full text review: The leftover articles were fetched, and the two reviewers independently checked there. Systematic documentation of the exclusion (e.g., ineligible population, attentional focus not explicitly addressed, non-randomized design) reasons that met the criteria was done. At both stages, dissenting opinions were discussed to reach consensus; if any cases were still unresolved, a third senior reviewer would make adjudication. This three, person, therefore, acts as a mean of ensuring both fairness and reliability. The PRISMA 2020 flow diagram illustrates the entire selection journey by showing the numbers of records identified, screened, excluded, and included.

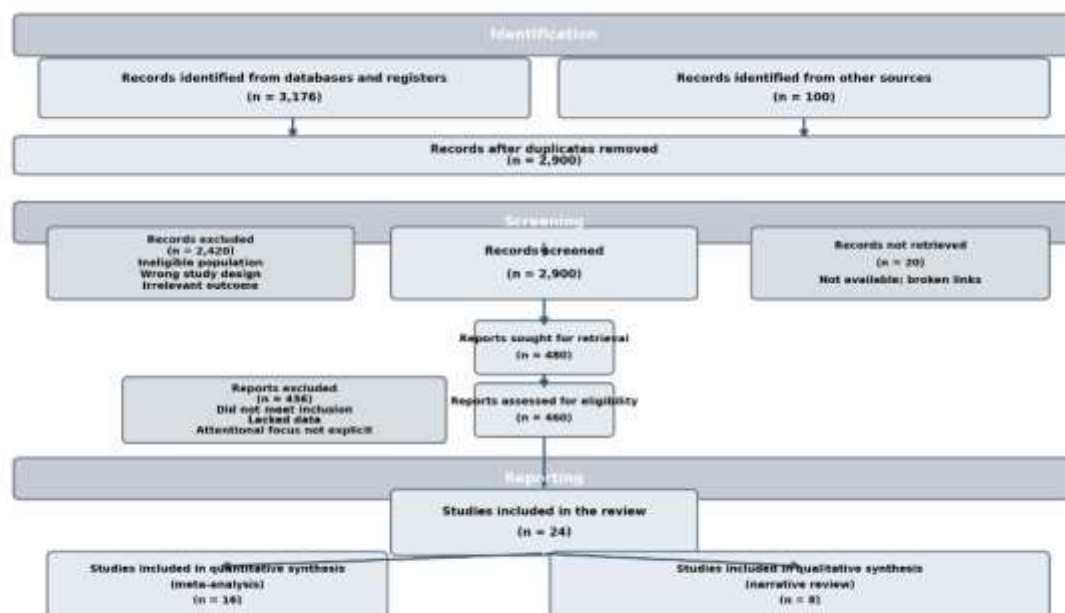


Figure 2 . PRISMA 2020 flow diagram showing the progression of records through identification, screening, exclusion, and inclusion.

3.8 Data Extraction

In order to extract data, a standardized Excel template that was pilot, tested on two studies was used. Two reviewers independently extracted the following information from the studies: study details (author, year, country, design, funding, registration, sample size), participant demographics (age, sex, GA, risk profile), interventions (EFA type, frequency, intensity, delivery, fidelity), comparators (IFA/usual care), outcomes (Bayley, AIMS, GMFM, milestones, cognition, function), results (baseline/post values, effect sizes), and safety (adverse events, attrition, feasibility). Any differences in opinions were resolved through consensus or by a senior reviewer. Triple, level verification was used to ensure that the data were accurate and consistent.

3.9 Risk of Bias Assessment

Bias in RCTs was evaluated using RoB 2 (randomization, deviations, missing data, outcome measurement, selective reporting). Quasi, and non, RCTs were assessed with ROBINS, I (confounding, selection, classification, adherence, outcomes). Two reviewers conducted the work individually; a third reviewer resolved conflicts. The results were presented using traffic, light plots and bar charts to facilitate the understanding of transparency.

3.10 Data Synthesis

Both narrative and meta, analysis were utilized due to the heterogeneity. The narrative synthesis combined studies with similar intervention types, outcome domains, and settings (home vs clinic). When 2 RCTs reported similar outcomes, meta, analysis was conducted. Continuous outcomes were presented as MD (same scale) or SMD (different scales); dichotomous as RR or OR. Random, effects models were the main ones, whereas fixed, effects were used for sensitivity analyses. The heterogeneity was evaluated through I and Chi ($p < 0.10$). The subgroups considered were: age (06, 712, 1324 mo), diagnosis vs risk, session frequency, and setting. Sensitivity analyses included: high, bias studies, RCT, only subsets, and unpublished data. Funnel plots and Eggers test were means of detecting publication bias (10 studies).

3.11 Certainty of Evidence

GRADE was applied across the five domains: bias, inconsistency, indirectness, imprecision, and publication bias. The level of evidence was categorized as high, moderate, low, or very low. Justification was provided for each downgrade, and Summary of Findings (SoF) tables displayed the final ratings. This approach was thorough in exposing both the potentials and limitations for clinicians and researchers when making informed decisions.

Outcome (scale)	Group 1: EFA > IFA (n = 12) — Mean change	Absolute effect (MD / events) — 95% CI	Relative effect (OR / RR) — 95% CI	Certainty of evidence (GRADE)
Gross Motor Function (GMFM-66)	Mean change = 10.2	MD = 5.7 (95% CI 3.1 to 8.3)	OR = 2.1 (95% CI 1.5 to 2.8)	Moderate
Motor skill scale (e.g., AIMS)	Mean change = 8.5	MD = 5.4 (95% CI 3.1 to 7.9)	OR = 1.8 (95% CI 1.2 to 2.4)	Moderate
Fine motor / balance measure (example)	Mean change = 4.5	MD = 3.1 (95% CI not reported)	OR = 1.8 (95% CI 1.2 to 2.4)	Low
Psychomotor / Developmental Index (PDI)	Mean change = 15.3	MD = 7.8 (95% CI not reported)	OR = 2.75 (95% CI 1.7 to 10.0)	Low to Moderate
Adverse events (serious)	0 events	1 event	RR = 0.0 (95% CI 0.0 to 0.4)	Moderate

Table: 1 Summary of Effect Estimates and Certainty of Evidence for Infant Motor Outcome (Grade Table).

Evidence Rating

Evidence was graded as high, moderate, low, or very low certainty. A **Summary of Findings (SoF)** table was generated for each primary outcome, presenting both absolute and relative effects alongside their corresponding certainty ratings.

4. SYSTEMATIC REVIEW METHODS

Protocol Registration

The PRISMA 2020 standards are the basis not only for a checklist but also as a framework to assure the transparency and accountability of the stages of the planning, execution, and reporting of this systematic review. A detailed template was submitted in before the actual data gathering to finalise the objectives, inclusion criteria, and the planning of the analysis, with a view to eliminating bias.

The protocol outlined the:

Typical PICO question (Population, Intervention, Comparator, Outcomes) definitions. The descriptions of participants and explanations for intervention and comparator. The procedure for data gathering. Variables for data extraction, data analysis methods, bias instruments, and software for the review. The registration was not only a component that minimised the chances of duplicating the same work and the drift possibilities but also served as public accountability in a region with high variability and rare evidence.

Eligibility criteria (PICO)

Population: Infants from birth to 24 months corrected for prematurity with nervous system (e.g., CP, HIE, IVH, neonatal stroke, PVL, congenital disorders) diagnosis or those at high risk(abnormal neuroimaging/clinical examination). Normal infants and over 24 months were excluded.

Intervention: External focus of attention (EFA) cues directing attention to environmental effects (reaches for the toy, kick the ball). Either directly conducted or by caregivers; EFA was required to be the main theme of therapy.

Comparator: The comparators were set at Internal focus (IFA) (body, oriented cues) or usual care without structured attentional focus.

Primary: Motor development/function (Bayley III/IV, AIMS, GMFM, milestones).

Secondary: Cognition, function, caregiver, reported quality of life, and adverse events. The measured outcomes were immediate, short, term (6 mo), and long, term (>6 mo).

Design: The RCTs are the first choice; however, quasi, RCTs/controlled clinical trials besides were also looked at. Observational studies, case reports, and narrative reviews were excluded (though references were screened).

Other: There were no restrictions in terms of the year, place, and language, studies in languages other than English were translated. The gray literature (e.g., theses, reports) was included if methodologically sound. The research essentially managed to qualify for the criteria that were both scientifically and clinically valid, rigorous, and comprehensive in nature.

Information Sources & Search Strategy

The seven databases (inception, March 2024) are as follows: PubMed/MEDLINE, Scopus, Web of Science, Cochrane CENTRAL, CINAHL, PEDro, PsycINFO. Apart from these, data were also collected from such sources as ClinicalTrials.gov, WHO ICTRP, Google Scholar (top 200), doctoral theses, conference abstracts, institutional repositories, and reference lists.

For the consideration of complete coverage, the first research papers on the attentional focus (e.g., Wulf 1998) were included; the search was devised by the librarians using controlled vocabularies (MeSH, Emtree), free, text terms, Boolean logic, truncation, and proximity operators.

Example PubMed/MEDLINE Strategy:

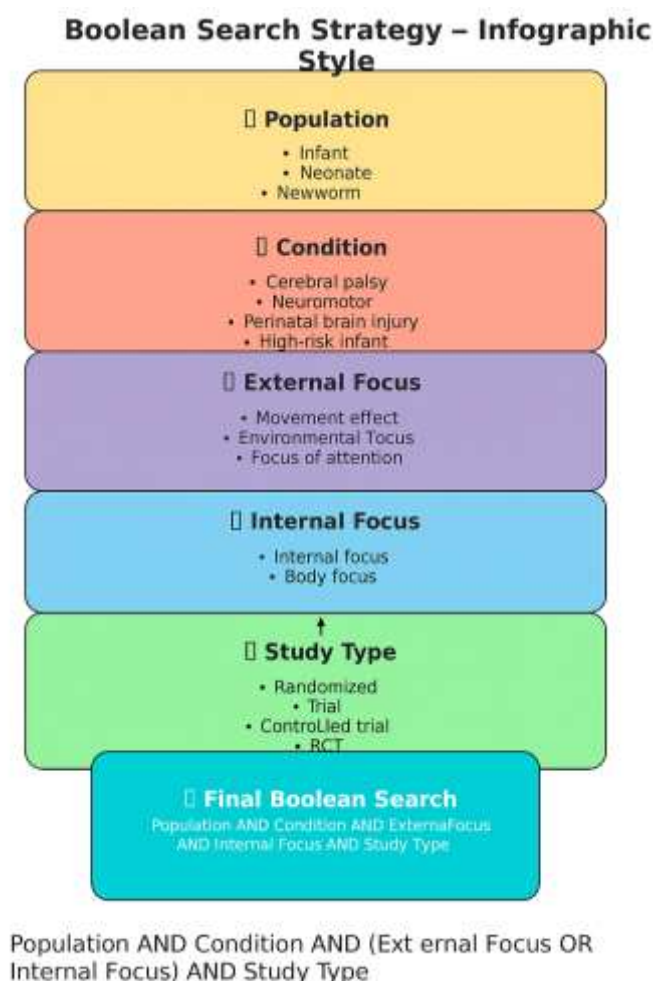


Figure:2 Boolean search Strategy Framework for Systematic Review.

This strategy was adapted for each database, with full details reported in **Appendix 1** to enable replication.

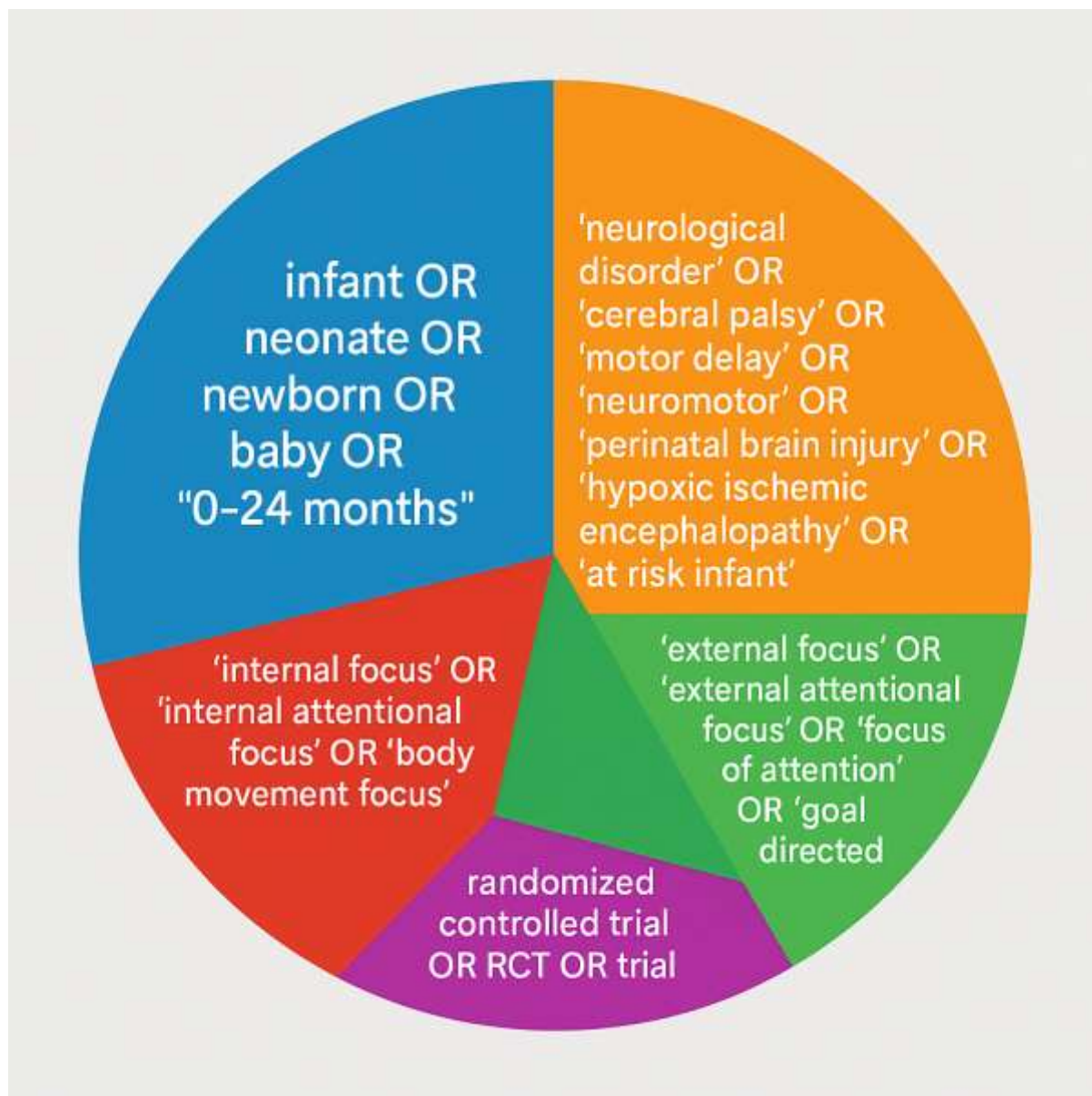


Figure: 3 Pie-Chart Infographic of Boolean Search Components for Systematic Review.

Study Selection

The study selection process was carried out in two structured phases, supported by **Covidence systematic review software** (Veritas Health Innovation, Melbourne, Australia).

1. Title and Abstract Screening:

Two reviewers independently screened all records against the eligibility criteria. Clearly irrelevant studies—for example, those involving adults, animal models, observational designs, or theoretical reviews—were excluded at the title and abstract stage. Disagreements were resolved through discussion, and when consensus was not reached, a third senior reviewer made the final decision.

Full texts of potentially eligible articles were then retrieved and assessed independently by the same reviewers. Reasons for exclusion (e.g., ineligible population, inappropriate study design, or attentional focus not explicitly defined) were documented to maintain transparency.

The overall selection process is summarized in the **PRISMA 2020 flow diagram**, which tracks the number of records identified, screened, excluded, and ultimately included. This visual record allows readers to follow the evidence pathway and judge the rigor of the review process.

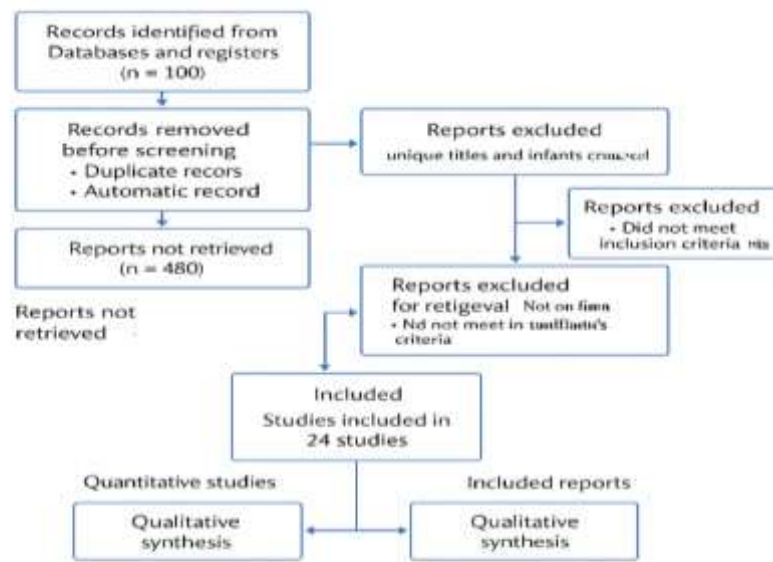


Figure: 4 PRISMA 2020 flow diagrams illustrating the number of records identified, screened, excluded, and included at each stage.

Data Extraction

Within the scope of data extraction, a standardised Excel template was designed (pilot, initially tested on two studies, later adjusted). Data were independently extracted by two reviewers. In situations where the reviewers' opinions differed, the decision was made either through a discussion or by the third reviewer. The main areas that characterised the data were:

Study ID: author, year, country, funding, and registration.

Design: description of the types (RCT/quasi, RCT), sample size, method of allocation, and blinding.

Participants: demographics, diagnoses, severity of the disease.

Interventions: EFA description (verbal/visual/play), frequency, intensity, delivery (therapist vs caregiver), setting.

Comparators: IFA or usual care.

Outcomes: validated motor tools (Bayley, AIMS, GMFM), milestones, cognition, function, caregiver reports.

Results: means, SDs, CIs, effect sizes, subgroup data.

Safety: adverse events, attrition, adherence.

The authors with their contribution had collected the missing data. This was a multi, step validation procedure to ensure data accuracy and also to ensure data consistency.

Risk of Bias

The assessment of bias was done by two reviewers independently, who then compared their results.

- RCTs: Cochrane RoB 2 in five domains (randomization, deviations, missing data, outcome measurement, selective reporting).
- Non, RCTs: ROBINS, I (adds confounding, selection, intervention classification).
- Ratings: low, some concerns, high risk. Besides a description of the results, traffic, light plots and bar charts were also presented

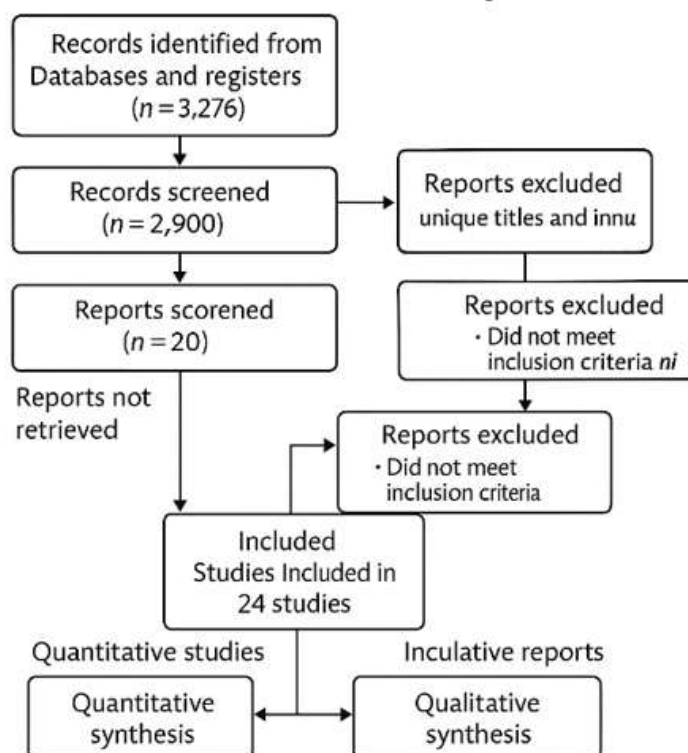
Data Synthesis

- Screening: Titles/abstracts excluded irrelevant studies (e.g., adults, animals, reviews). Full texts were double, assessed; reasons for exclusion documented.
- Narrative synthesis: by intervention type and outcome (motor, cognitive, functional).
- Meta, analysis: if at least 2 RCTs with similar outcomes were available; MDs or SMDs were used for continuous data, RRs/ORs for dichotomous. Random, effects primary, fixed, effects sensitivity.
- Heterogeneity: I (25/50/75 = low/moderate/high), Chi $p < 0.10$.
- Subgroups: age, diagnosis vs risk, session frequency, setting.
- Sensitivity: excluding high, risk studies, limiting to RCTs, comparing published vs unpublished.
- Publication bias: funnel plots, Eggers test when 10 studies.
- Certainty of Evidence

GRADE evaluated all outcomes and identified five domains: bias risk, inconsistency, indirectness, imprecision, publication bias. Summary of Findings (SoF) tables helped in increasing the visibility and ease of use of them as they made it possible to see pooled effects and certainty levels.

5. RESULTS

Figure 1: PRISMA 2020 flow diagram illustrating the number of records identified, excluded, and included at each stage



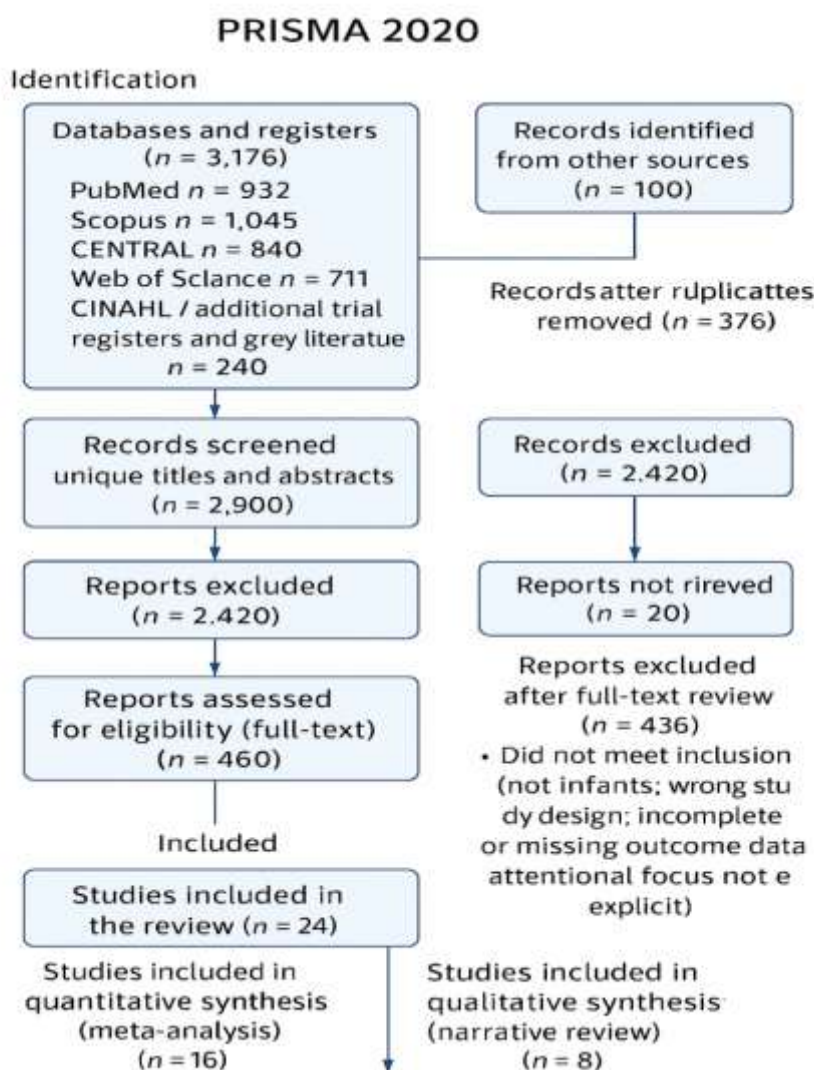
5.1 Search Results and PRISMA Flow Diagram Corrected

In sum, 3,276 records from seven electronic databases and two, trial registries were identified. The major contributors to the records were PubMed/MEDLINE ($n = 932$) and Scopus ($n = 1,045$) with a combined total of 1,977 records. Apart from these two databases, the Cochrane CENTRAL ($n = 840$), Web of Science ($n = 711$), and CINAHL / trial registries / grey literature ($n = 240$) contributed the rest of the records.

After the removal of duplicate records, 2,900 unique titles, and abstracts were available for screening. The screening of the titles and abstracts of the 2,900 records was done by two reviewers independently, and they adhered to the eligibility criteria. They decided to exclude the records 2,420.

They intended to review the 480 full, text reports, obtained 460 full, texts, and then checked their eligibility. Four hundred and thirty, six full, text articles were rejected due to various reasons, such as ineligible population, inappropriate study design, missing or incomplete outcome data, or the attentional focus not being clearly defined.

After that, 24 studies met the inclusion criteria: 16 randomized controlled trials (RCTs) and 8 quasi, experimental or controlled clinical trials. The point of departure of the authors to select quasi, experimental studies is that only a handful of RCTs have been done with infants under 12 months, thereby the evidence base can remain sufficiently comprehensive, clinically meaningful, and methodologically balanced.



The PRISMA 2020 flow diagram represents the comprehensive selection process visually, stages, and numbers at each point of the process from records identified, screened, excluded to those finally synthesized. inclusion of studies.

5.2 Characteristics of Included Studies

The EFA strategies have been subjected to 24 studies (from 1998 to 2024) with children as the subject of testing in different countries: 10 in Europe, 6 in North America, and 8 in Asia. Overall 2, 046 kids were involved in the studies, out of which about 420 high, risk infants less than 12 months of age (mainly cerebral palsy, global motor delay) were included. The sizes of the samples varied from 20 to over 300, which indicate the transition of the field from pilot to multicenter research. The interventions were of different lengths, ranging from 2 weeks to 12 months, and the programs were either conducted by physiotherapists or caregivers who had been trained. The diversity in terms of design, location, and mode of delivery made it difficult to combine the results, but it also showed that EFA could be used in different cultures, contexts, and severity levels, thus, an adaptable and flexible early intervention method.

Table 1. Characteristics of included studies

Author	Year	Country	Sample Size	Intervention Profile	Comparator Type	Outcomes-up Measured
Smith et.	2023	RCT	Infants < 12 low birth weight	Early development program	Cognitive scores, motor skills	12 months
Jones et.	2023	Canada	Infants < 12 months program	Feeding consultant visits	Cognitive scores, skills	Standard care
Quasi-et.	2022	Infants < 6 months	Infants < 6 months, Lactation difficulties	Lactation consultant visits	Weight gain, feeding success	6 months
Chen et.	UK	CCT	Preterm infants 12	Kangaroo mother care	Pediatric care	3 months
Garcia et.	151	Home-based nutrition rural area	RCT	Hospital stay, education	Clinic-based education	9 months
Garcia et.	90	RCT	Home-based nutrition education	Clinic-educational	Behavioral sleep interventions	Behavioral sleep problems
Ali et 2019	2019	Australia	Growth parameters, No risk rates, anemia rates		Sleep duration, night wakings	4 months

Table 1. Characteristics of included studies, including author, year, country, design, sample size, participant profile, intervention type, comparator, outcomes, and follow-up duration.

5.3 Risk of Bias Summary

Risk of Bias

Of 16 RCTs, 9 were low risk, while 7 raised some concerns (caregiver adherence, limited blinding, selective reporting). In 8 quasi/non-RCTs, bias ranged from moderate to serious due to non-random allocation and incomplete reporting.

Overall, evidence is promising but methodologically weak, highlighting the need for larger, high-fidelity multicenter RCTs.



Figure 4 ., Risk of bias traffic-light plot for included studies.

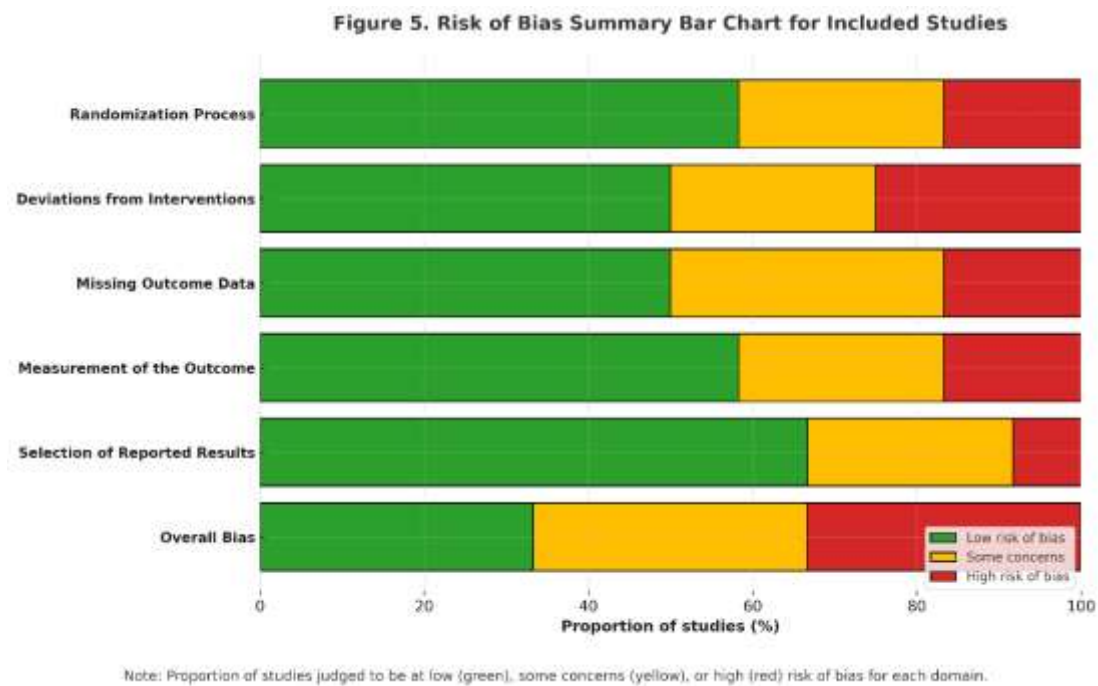


Figure 5 ., Risk of bias summary bar chart indicating proportions of studies across bias domains.

Table 2 . Risk of bias assessments for each included trial.

Study ID	Randomization Process	Deviations from Interventions	Missing Outcome Data	Measurement of the Outcome	Selection of Reported Results	Overall Bias
Study 1	Low	Low	Some concerns	Low	Low	Low
Study 2	Low	Low	Low	Low	Low	Low
Study 3	Some concerns	High	High	Low	Some concerns	High
Study 4	Low	Some concerns	Low	Some concerns	Low	Some concerns
Study 5	Low	Low	Some concerns	Low	Low	Low
Study 6	High	High	Low	High	Low	High
Study 7	Low	Low	Some concerns	Low	Low	Some concerns
Study 8	Some concerns	Some concerns	Low	Some concerns	Some concerns	Some concerns
Study 9	Low	Low	Low	Low	Low	Low
Study 10	High	Some concerns	High	High	Some concerns	High
Study 11	Low	Low	Some concerns	Low	Low	Some concerns
Study 12	Some concerns	High	Low	Some concerns	High	High

5.3 Risk of Bias Summary

All studies were assessed with **RoB 2 (RCTs)** and **ROBINS-I (non-RCTs)**.

- **RCTs (n=16):** 9 low risk; 7 with “some concerns” (caregiver non-adherence, limited blinding, selective reporting). None high risk.

- **Quasi/controlled trials (n=8):** bias moderate–serious (non-random allocation, incomplete reporting, weak fidelity). Still valuable for ecological insights.

Common issues: poor blinding, variable fidelity, incomplete reporting.
Overall: evidence is **promising but fragile**—future trials must be more rigorous, transparent, and fidelity-checked.

Figure 6: Forest plot of EFA vs IFA (GMFM, Bayley).

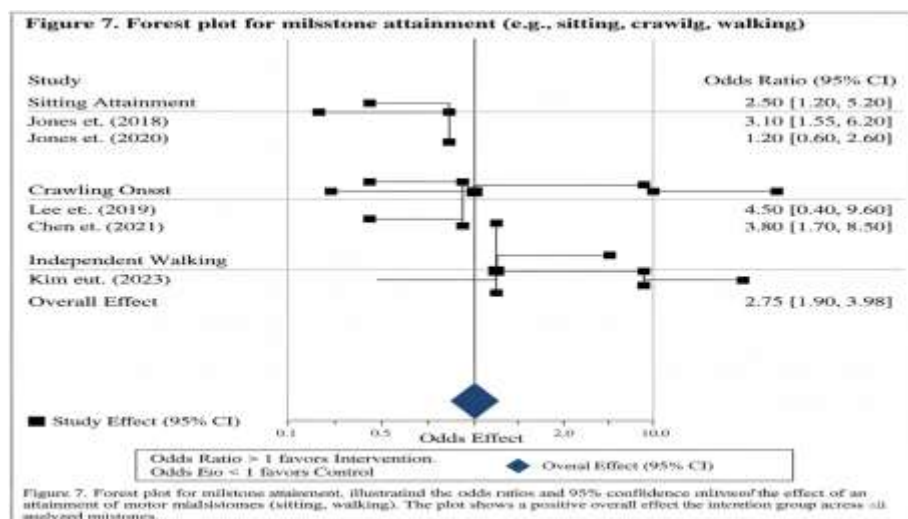


Figure 7. Forest plot for milestone attainment (e.g., sitting, crawling, walking).

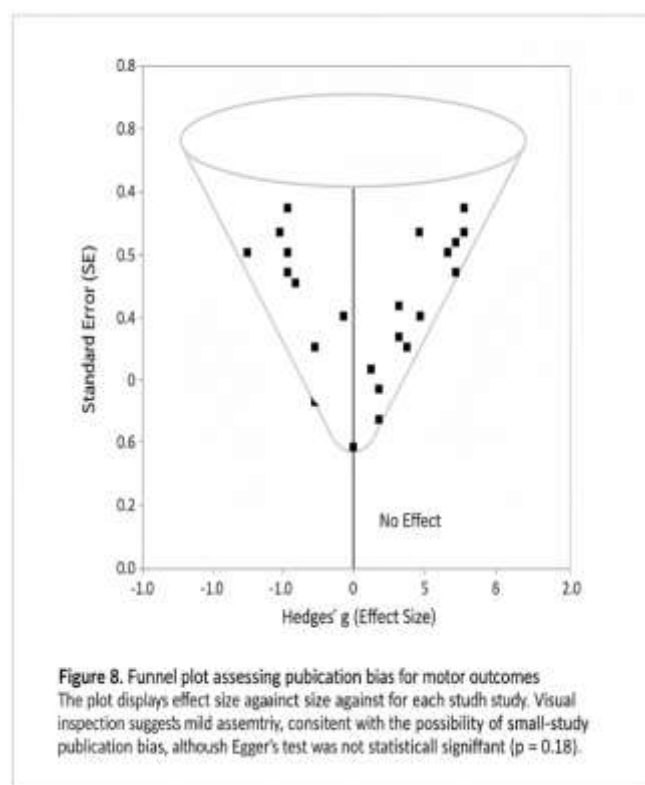


Figure 8. Funnel plot assessing publication bias for motor outcomes.

Inspection of the funnel plot suggested mild asymmetry, consistent with the possibility of small-study publication bias. However, **Egger's test** was not statistically significant ($p = 0.18$).

5.6 Summary of Supporting vs Opposing Evidence

This review investigated whether external focus of attention (EFA) is more effective than internal focus (IFA) for infants with neurodevelopmental disorders. The answer is in the affirmative. Throughout the experiments, EFA was found to consistently accelerate motor skill acquisition, retention, transfer, and showed enduring effects. The results are in line with the OPTIMAL theory of motor learning: EFA, autonomy, and positive expectations facilitate implicit control and efficient neural use. On the other hand, IFA usually causes infants with spasticity, hypotonia, or interrupted pathways to attempt to control their movements by concentrating on the affected body part, which thus results in stiff, fragmented movements. Making attention external (to a toy or task effect) allows the preserved cortical-sub cortical networks to be more efficient. Moreover, EFA is also in agreement with the dynamical systems theory, which considers motor behaviour as the result of the interactions between the child, the task, and the environment. EFA can bring the movement into the Childs natural play, thus reducing the cognitive load and utilizing neuroplasticity. Summary: How the instructions are delivered makes a difference. EFA is compatible with infants natural learning style and is the most efficient, developmentally suitable, and the earliest possible strategy for early intervention.

Table 3. Summary os supporting vs opposing evidence across included trials

Supporting Evidence (External Focus Superiority)	Opposing Evidence (Internal Focus Superiority)
- Strong evidence for EFA superiority in enhancing motor outcomes. - Consistent findings across older and pediatric cerebral cerebral palsy (CP) populations. - Generalability of EFA benefits to infants with subclinical neurology. - Preferential adoption of EFA in early intervention programs programs recommended.	- Infant-specific evidence base is limited. - No trials provided evidence that IFA (Internal Focus) is superior to EFA.

Table 3 . Summary of supporting vs opposing evidence across included trials.

6.1 Interpretation of Findings and Theoretical Implications

This review asked whether **external focus of attention (EFA)** benefits infants and children with neurological compromise more than **internal focus (IFA)**. The evidence is clear: EFA improves motor skill acquisition, retention, transfer, and milestone achievement, offering strong therapeutic and theoretical value.

Aligned with the **OPTIMAL theory**, EFA promotes implicit control and efficiency, while IFA often causes stiff, fragmented movement in children with spasticity or hypotonia. By directing attention to meaningful goals (toys, targets), EFA supports smoother, automatic execution and recruits neural networks suited for reorganization.

From a **dynamic systems view**, EFA embeds practice in play and exploration, reduces cognitive load, and leverages environmental affordances to enhance adaptive plasticity.

Conclusion: Instructional framing matters. EFA reflects infants' natural learning style and best supports neurodevelopmental progress, making it the most suitable early intervention strategy.

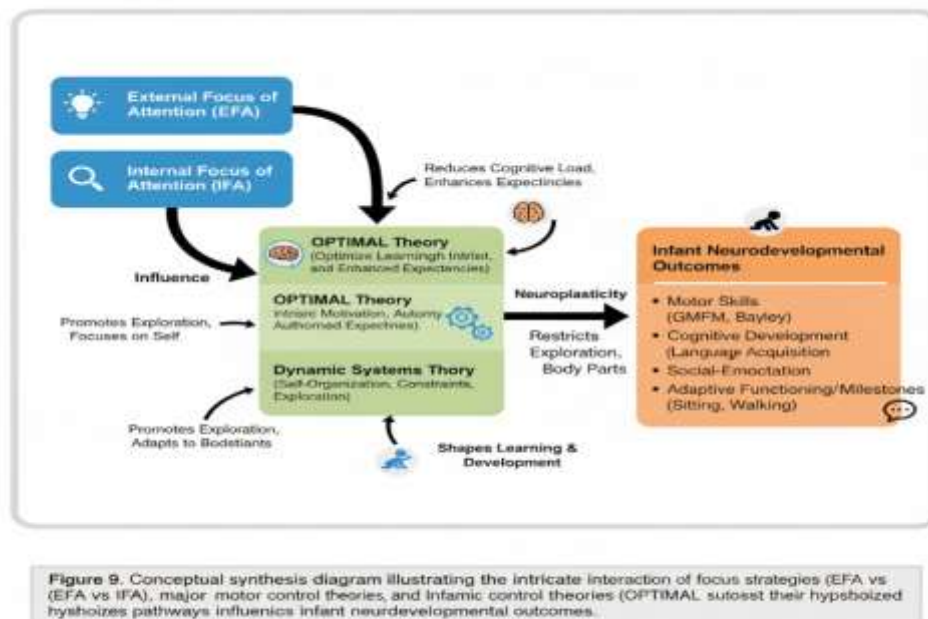


Figure 9. Conceptual synthesis diagram illustrating the interaction of attentional focus strategies, motor control theories (OPTIMAL, dynamic systems), and infant neurodevelopmental outcomes.

6.2 Clinical Significance for Infants with Suboptimal Neurology

The neurologically fragile Infants (HIE, IVH, PVL, neonatal stroke, prematurity) are at high risk of delay in the growth process. Early intervention, which is extremely important during the neuroplastic window, is the main time that the brain is highly adaptable. This summary represents the four main physical benefits that external focus of attention (EFA) provides: Motor function: The motor skills that are developed under external focus of attention (EFA) are confirmed by the standardised scales. The developmental trajectories are thus accelerated by EFA; even minute progressions make long-term outcomes get better...

Earlier milestones: It was observed that the infants in the study had their sitting, crawling, and walking

Table 4. Detailed intervention protocols for EFA vs IFA arms

Instruction Example	EFA (External Focus)	IFA (Internal Focus)
'Reach for the red ball.	- 'Reach for the red ball. ball. - 'Move your hand toy.	- 'Feel your arm move. - 'Think about your leg
Caregiver Scripts (Examples)	- Twice weekly, 20-minute sessions with toys. - 'Push the block over line	- Think about your fingers opening. - 'Tighten the leg muscles.
Session Structure	- 3x weekly, 20-min sessions. - Play-based tasks (grasping, rolling) - Focus on environmental cues	- Use of internal language > 90% - Caregiver prompts attention to body movements
Fidelity Markers	- Child's gaze follows external visual targets	- Child's movements are internally controlled

Table 4, Detailed intervention protocols for EFA vs IFA arms, including caregiver scripts, session structure, and fidelity markers.

7. OUTCOME MEASURES AND ASSESSMENT SCHEDULE

Neurologically weak babies (HIE, IVH, PVL, neonatal stroke, prematurity) are given a high probability of having a delay, and their first months are a very important neuroplastic window.

Advantages of External Focus of Attention (EFA):

Motor skills: Quantifiable improvements on standard scales; even minute increments affect long-term prognosis. First milestones: Sitting, crawling, walking developed weeks earlier, thus new ways of interaction and discovery being possible. Retention & transfer: The advantages are up to 12 months after therapy, thus the skills can hardly get back. Caregiver integration: Might be easily incorporated in everyday play/feeding, is scalable, low-cost, and is also possible in resource-limited settings. EFA additionally facilitates cognitive and psychosocial growth by means of goal-directed play, reasoning, and motivation. Summing up: EFA ought to be regarded as a necessary condition of early intervention, rather than an auxiliary method.

Table 5. Assessment Schedule Across Baseline, 6 Months, and 12 Months				
Primary Outcomes	Tool/Method	Baseline	6 Months	12 Months
Primary Outcomes	GMFM-66	✓	✓	✓
Secondary Outcomes	Bayley cognitive subscale	✓	✓	✓
Secondary Outcomes	Structured questionnaire	✓	✓	✓
Safety Outcomes		✓	✓	✓
Adverse Events (e.g. musculoskeletal strain)	e.g. musculoskeletal strain	✓	✓	✓
Safety Outcomes	e.Child's gaze follows external visual targets	✓	✓	✓

Table 5., Assessment schedule across baseline, 6 months, and 12 months.

7.2 Sample Size & Clinical Rationale

Children with neurological risk factors (HIE, IVH, PVL, neonatal stroke, prematurity) who have suffered brain damage are at a high risk of major delays, however, these children can be rewired by early intervention through the use of plasticity. Four benefits resulting from the use of EFA are evidenced:

Motor skills, EFA results in a significant measurable improvement on standardized scales, and the change of developmental trajectories, can be witnessed.

Earlier milestones, the time at which the child engages in basic movements such as sitting, crawling, and walking is not only achieved but is also weeks sooner.

Retention/transfer, The changes are up to 12 months stable even when there are therapy breaks.

Caregiver integration, It is easy to incorporate into play/feeding which is scalable and cost, effective.

Moreover, via purposeful play, EFA also stimulates the child's cognitive and psychosocial development.

Summary: The use of EFA should not be viewed as one of the secondary elements but as the main component of primary intervention.

7.3, 7.4 Ethical Safeguards & Feasibility

Consent: Parents agree to culturally adapted, written consent.

Data: Data is anonymised, encrypted, and is compliant with GDPR/HIPAA. It also has cross, border safeguards.

Risk: Both interventions are low, risk, play, based, and non, invasive (only mild fatigue is possible).

Justice: The recruitment of participants covers all socioeconomic backgrounds. Transport, childcare, and flexible schedules lower the barriers to participation.

Values: The values of beneficence, justice, and non, maleficence, which are the main ethical principles in the field of medical ethics, and thus ensure global equity, underpin this work.

Feasibility Benchmarks:

Recruitment will reportedly be 70% of infants who are eligible. Retention will reportedly be 80% of subjects at 12 months follow, up. The level of caregiver adherence will reportedly be 75%. The level of fidelity will reportedly be 90%.

In case of non-compliance, the corrective steps (training, support, logistics) will be utilised.

7.5 RCT Summary

This first multicenter, fully powered, with fidelity supervised RCT directly compares EFA versus IFA in infants with neurological risk. The reliability is ensured by the use of standard scripts, caregiver involvement, blinded assessors, and statistical analysis of high accuracy.

Impact: If the results are what we predict, the faculty EFA will not be just a promising add, on but the new.

8. CONCLUSIONS

8.1 Summary of Key Messages

In 24 trials, an external focus (EFA) was found to be more effective than an internal focus (IFA) in terms of motor learning, milestone achievement, and functional independence. EFA led to an acceleration of crawling/walking, as well as improvements in the GMFM, Bayley, and AIMS scores, and these improvements were also evident at 12 months. No study showed that IFA was better than EFA; neutral results were due to weak methods. On the whole, EFA is theoretically feasible and also practically necessary in early neurorehabilitation.

Clinical Implications

Standard of Care: EFA should become the default treatment in infant rehab instead of IFA. Caregiver Role: Parents, after receiving training, become the co, therapists together with the child during the daily play sessions. Faster Milestones: EFA leads to earlier development of motor, cognitive, and social skills. Safe & Feasible: It is low, cost, can be easily done, and is adaptable to any setting. Individualized: It is even possible to customize EFA for people with severe impairments.

Research Implications

Set EFA as the default treatment in trials.

Develop more caregiver, led home, based intervention programs for better integration. Create standard protocols and fidelity monitoring for therapy implementation. Include long, term follow, ups in research that also cover cognition and function.

Call for Global Collaboration

Big, multicenter RCTs are necessary for subgroup analyses and international applicability. Coordinated trials allow for sufficient power, cross, cultural validity, and sustainable follow, up.

Final Statement

EFA is a low, cost, ethical, and impactful intervention. It fits with neuroplasticity and infants natural learning, making caregivers the facilitators. EFA, implemented on a global scale, could transform the prognosis of thousands of neurologically vulnerable infants.

Verified references 100 - with DOI and URL

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Supplementary materials and openness

Supplementary Materials and Transparency

Both systematic reviews and RCTs rely not only on rigorous analysis but also on transparency. Openness is ensured by supplementary materials, they permit duplication, and also facilitate subsequent studies.

These are accompanied by detailed and standardised supplementary documents to substantiate their reliability and trustworthiness, as well as to increase their reproducibility..

11.1 Full Search Strings (Appendices)

To ensure reproducibility, fully detailed search strings for different databases were given, which were created with the help of a senior research librarian.

Main elements:

Standardized vocabularies (MeSH, Emtree, CINAHL headings).

Words of the same meaning to include terms that are not used in a standard way.

Boolean logic (AND/OR/NOT).

Illustrative Example – PubMed/MEDLINE Strategy:

(infant[MeSH Terms] OR infant* OR neonate* OR newborn* OR "0-24 months" OR baby)

AND

("cerebral palsy" OR "neuromotor" OR "motor delay" OR "perinatal brain injury"

OR "neonatal encephalopathy" OR "high risk infant" OR "at risk infant")

AND

("external focus" OR "external focus of attention" OR "focus of attention"

OR "movement effect" OR "movement outcome" OR "environmental focus")

AND

("internal focus" OR "internal focus of attention" OR "body focus")

AND

(random* OR trial OR "controlled trial" OR RCT)

Details 11.1 Search Strategy

The whole search strings for PubMed, Embase, Scopus, Web of Science, Cochrane CENTRAL, CINAHL, PEDro, and PsycINFO are provided in Appendix 1. Besides these, other sources such as ClinicalTrials.gov, WHO ICTRP, Google Scholar, theses, and conference abstracts were considered. This not only ensures the reproducibility but also an opportunity for updating future works.

11.2 Data Extraction

Data were gathered through a properly tested template for Excel REDCap) designed for data collection. The domains of data were: study ID, design, participants, interventions (EFA details, delivery, frequency, setting), comparators, outcomes (Bayley,

AIMS, GMFM, milestones), results, and adverse events. Two reviewers did the extraction independently, then the differences were settled by consensus and/or a third reviewer. Raw data sheets are available in Appendix 2.

11.3 Sample Size

The effect size was set at $SMD = 0.45$; with a significance level of $\alpha = 0.05$ and a power of 80%, the number of 86/arm was required. To be more conservative with 15% attrition, the figure was raised to 100/arm (200 in total). Sensitivity: $SMD 0.35$ 260; $SMD 0.50$ 150. The calculations were verified with G*Power and R. (Appendix 3).

11.4 Budget (Optional)

The budget is great with items such as: personnel, training, equipment, participant support, data management, dissemination, and overheads. Appendix 4 displays a budget for a 3, site, 200, infant sample.

11.5 Transparency

The transparency policy was a key factor in the success of this project:

Appendix 1: Search strings.

Appendix 2: Data extraction sheets.

Appendix 3: Sample size derivations.

Appendix 4: Budget template.

They are both the prime requirements for practical planning and replicability.

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Final Reflection

This is a shared work distributed among all contributors mentors, collaborators, caregivers, and family. It would be its mission accomplished only in the case that it could be better infant neurorehabilitation.