# The Neuroscience of Play
(A report on the literature)

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## Executive Summary

**Rationale:** Neuroscience research has been present for many years now, however the emerging branch of Neuroeducation – brain science focused on children and child development – has created a need to explore in further depth the workings of a child's brain. Whilst the literature is starting to grow around brain development in children, there is little to show for what happens in a child's brain when they are engaging in play-based activities and learning. For adults to understand this important part of child development, research needs to be carried out to examine what the role of the adult is and the types of external influences that should be encouraged. For this to happen, an extensive search of the current literature around neuroscience and play needs to be carried out to enable firm next steps in research to be devised. This report outlines the key findings from an initial scoping literature review and provides direction for further study.

**Methods**: A scoping literature review was carried out on Norland's online platform Discovery. Findings were extracted and inserted into a summarised table format where a thematic analysis was carried out to analyse and code the findings and create themes to give further searches direction.

**Results:** Key findings have been outlined in this report under each theme:

- **Tools**: Due to ethical restrictions there are a limited number of studies relevant to this research with those studies that are relevant using tools such as MRI, CT and PET scan technology.
- **Types of Play:** Physical, social, thematic and dramatic play all aid in brain development, specifically Rough-and-Tumble play (RTP) which aids in decoding emotions and helps foster a sense of safety whilst developing the social brain. Meaningful play with novel and familiar things helps the child to make sense of what they are learning, and repetition has proved to be vital in strengthening neural connections.

- **Role of the Adult / Environment**: Adults and the environment are critical for the developing child. The interactions between adult and child, and the environment in which these interactions take place are a crucial catalyst in how that child's brain develops. The genes in the brain modify and change based on the environment and its influences, strengthening the importance of the adult and how those adults frame the surrounding environment. The generation of neurotransmitters and hormones are just as important as activating specific parts of the brain when playing. Language acquisition and social contact effects changes on the brains white and gray matter.
- **Brain Regions:** The architecture of the brain is established in the early years by both genetic and environmental influences. The brain is hardwired to perform tasks such as breathing, circulation and reflexes, and softwired to adapt to external stimuli and develop. Animal studies have supported the idea of play influencing the brain development of children.

**Implications:**

- Further research is required to explore this topic in more depth via a wider range of outputs.
- Adults need to be better supported to learn and develop their understanding of child neuroscience and how they can help.
- Policy makers should acknowledge the importance of the adult and environment on brain development and support the industry accordingly.

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## Introduction

"Neuroscience is reforming practice and policy" (Wasserman & Zambo, 2013, p.16) and because of this, educators, carers, teachers, practitioners, all have a responsibility to learn and understand their role in neuroscience and education. Why did that child choose this activity? Why did they not follow the other children to the role play, but instead chose the geometric tiles? What outside influences and stimuli are affecting what these children are doing, and the way in which they are behaving? Neuroscience is helping us to answer these questions.

This report presents the findings from a research project carried out by Dr Janet Rose and Lucie Hamilton, graduate research intern (GRI), looking at the neuroscience of play and, specifically, what the current neuroscience literature says about the development of children's brains when they participate in play activities and what this means in terms of the implications for practice.

Neuroscience was embarking on rapid growth through the 1990s due to advancement in technology and, as a result, neuroscientists began to get insights into brain development and how the brain functions when learning. However, when looking at neuroscience in conjunction with children and education, challenges begin to emerge. Attempting to translate the technicalities of neuroscience into jargon-free, accessible information for the care and education workforce is not an easy, or straightforward task (Wasserman & Zambo, 2013), but it is a necessary one. Educational Neuroscience (neuroeducation) is an

emerging field of research studying the relationship between biological processes of the brain and students' cognitive development, with a growing focus of neuroeducation in preschool education (Allee Herndon & Killingsworth, 2018).

Learning through play is a key aspect of children's development and is essential for "quality early childhood pedagogy and education" (UNICEF, 2018, pg 4). It has been widely recognised as a reputable means of provision in early years settings. This is because early years professionals understand the importance of play and the benefits this activity has on child development. Play has earned new respect as biologists, neuroscientists, psychologists, and others see that play is equally as important as other basic drives of sleep, rest and food (Frost 1998). This has not always been the case, with rote memorisation and information recall remaining the norm in many countries (UNICEF, 2018) and at a societal level, we are still yet to institutionalise the power of learning through play (Panksepp, 2007). Over the years, research has been carried out to support the idea that playing is beneficial to children's holistic development; physically, emotionally and cognitively, although a vast amount of this research focuses on the observational and behavioural element of play and theorises what this means for development. A lot of studies focus on child behaviour, not brain, and are not based on technologies which image the brain. Most of what is known about the function and development of children's brains has been inferred from studies of perception, cognition and affect – not neuroanatomy (DiPietro, 2000). The growing literature of play over the recent years has begun to look more specifically at brain activity and how play affects the physiological and biological make up of a child's brain. This type of research into play is especially useful in terms of supporting the theory that is already widely understood and strengthening the argument that play is not simply a waste of time or 'just playing', but a vital part of a child's learning and development.

However, when conducting a review of the current literature, it became clear that this is still a vastly under-researched area of child development and one that needs further expansion.

## Methodology

The purpose of our study was to look at the current literature around children's brain development specifically linked to play activities and try to draw out some key messages for practice. Therefore, it was decided that a scoping review of the literature to identify the body of research that has been written on this topic was the best strategy to begin with. We chose to follow Arksey & O'Malley's five stage process for scoping review (2003) to identify the research already present, clarify key concepts and attempt to identify gaps in the subject.

The literature search was conducted with the following research questions in mind:

- What does the literature say about how brain development is affected by play activities?
- What key messages can be ascertained that have implications for early years practice.

The search was carried out on Norland's platform, Discovery, which is a search platform that subscribes to fourteen databases such as ERIC, MEDLINE, Child Development and Adolescent Studies, Education Research Complete and many more. Based on the topic of our study and looking at the databases Discovery subscribes to; it was decided that an online search on Discovery was sufficient for this initial stage of this research.
The initial search was based upon our primary discussion at the beginning of the project where we identified the parameters of our research, selected a few key words and discussed our aims for the project. Once a selection of articles had been read and summarised, initial themes began to emerge from the data. These preliminary themes generated further key words to search on the second round. From here, a summary document was created with the five themes identified and coded; *tools and/or machines used to study the brain, types of play, role of the adult, environment and brain regions*. From here, a more detailed search of the literature followed, incorporating key words from the initial themes. An individual key word/phrase search was the starting point, followed by a category search combined with our key demographic of participants, children. The final search term was then created, incorporating the key words from all categories and the participants required. This generated a final search number of 5417 texts. Due to the nature of this research being specifically about children and the effects on the child's developing brain, a further restriction was applied with the participant and brain region key words being applied to abstract only and the remaining categories for a full text search. This brought the final literature search down to 574.

The final search term was conducted as an advanced search with the following parameters applied to enable a relevant return of the literature; peer reviewed, between 2001-2021 and written in English. These texts were read, summarised and placed into the relevant categories. This enabled a thematic approach to analysis for the key findings. The thematic approach undertaken followed Braun & Clarke's (2006) six phase model.

## Key Findings

### *Tools and/ or machines used to study the brain*

There could be several reasons why there is a lack of evidence on children's brains and how they develop and function during play activities, but one such reason that appears to be recurring in the current scope of literature is that there is a difficulty in finding valid and reliable ways of testing for the age group we are looking at (0-8). It seems that most tests are appropriate for adults, and even older children, but appear to prove challenging to modify for preschool age individuals (Kelly, et al, 2011). A common thread throughout the literature shows the machines often used for observing activity in children's brains are Magnetic Resonance Imaging (MRI), Diffusion Magnetic Resonance Imaging (dMRI), Functional Magnetic Resonance Imaging (fMRI), computerised axial tomography (CAT/CT scan) and Positron emission tomography (PET scan). Electroencephalogram (EEG) machines are a more commonly used tool in measuring activity in a child's brain, however this is a distal measure detected at the scalp and therefore could be argued to be less detailed and thorough (DiPietro, 2000). Ethical concerns currently prevent the use of these tools as routine for normally developing children (DiPietro, 2000) and it is because of these ethical concerns, neurobiological research tends to be carried out on animals to reveal how the specifics of the brain work (Panksepp, 2008).

***Types of Play***

According to Neale, et al (2018), “play is a highly complex social interactive activity that activates a combination of sensorimotor, cognitive and socio-emotional neural circuits” (Pg 4), with Panksepp (2007) agreeing that the urge to play is a neurological drive. So, it became essential to look at the different types of play and how these variations impacted the learning and development in the child's brain.

Recent research in neuroscience has suggested that play behaviour is based around three neural circuits controlling motivation and affect, motor performance and executive functions (Neale, et al, 2018). Some investigators believe there to be a collaboration between cognitive and bodily knowledge, proposing that children learn through the movements their bodies make, rather than just verbalisation and recollection of information alone. It is believed that by unrestricting a child’s movement, their learning can be enhanced due to their engagement with the external properties of their environments (McLaren, et al, 2011). Mavilidi, et al (2017) supports this view, adding that physical activity has been related to benefits with cognition such as enhanced development with the brain by means of improved blood flow, neural connections and oxygenation. Cognitive function and academic performance have also been noted in this study as being related to the physical element of activities. This would suggest that active game playing, and sports, are benefitting children in more ways that just physically, a notion supported by Damiano (2006) who highlights the importance of motor activity to establish and reinforce the neural pathways in the brain.

Another form of physical play that appeared frequently in the literature supporting the idea that this type of play links with cognitive benefits is Rough-and-Tumble play (RTP). Panksepp (2007) believes this type of play to be a “wonderful evolutionary tool” of the mammalian brain, that helps to achieve full socialisation (pg, 60). RTP is known to stimulate development within the brain alongside promoting social competence and helping to decode emotional cues, especially when playing rough and tumble with parents (Fletcher et al, 2011; Hassinger-Das, et al, 2017). Using this safe environment to play within, and with a loved one, the child can regulate their heightened emotions appropriately. There is also additional evidence available from animal studies that suggest how RTP stimulates brain development leading to improved performances cognitively (Fletcher et al, 2011).

When looking at play and the brain, we must not always look at more physical types of play, but also a range of other types too. Dramatic, imaginary and thematic play all help to develop executive function as well as things like games and puzzles (Allee-Herndon & Killingsworth, 2018). Moreno et al, (2017) also claim that mature dramatic play develops executive functions, such as attention-shifting, memory, higher order thinking and inhibitory control. Meaningful play and experiences also use multiple networks in the brain to make sense of what the child is learning. It has been suggested that not only play with familiar items, but also play with new, novel items and experiences help to develop cognitive processes and strengthen memory (Lui & LEGO, 2017). In a study by Guyer et al (2018), the infant brain, between 6-9 months, showed plasticity after repeating learning with novel objects. This shows how simple, repetitive infant games help to strengthen and shape the neural connections and pathways. What appears to be a simple game of peek-a-

boo, is actually helping to improve the child's cognitive responses. The more complex these neural structures are, the more it influences further complex play moving forward (Frost, 1998).

A brief acknowledgement to school readiness as this is a term used often when thinking about pre-schoolers and learning through play. School readiness is not just related to ideas around academic performance and progression. A lot of people associate the term with being able to get dressed, hold a pencil, count and the like. However, school readiness pertains to physical, social and emotional progress and these skills are developed through purposeful play (Harte & Gilbert, 2011). This leads us onto the next section about the role of the adult in play.

***Role of the Adult / Environment***

It would be easy to concentrate on the specifics of the brain and play itself when looking at early childhood neuroscience however, it must be acknowledged that there are some other important factors to consider, for example, the role of the adult and the environment. These two areas work hand in hand so therefore they will be addressed together.

Leisman et al (2015) place an emphasis on the teachers of young children, calling them "critical" for the basis of the developing child and, consequently, the neurological adult (Pg 80). This is a view supported by many, including Rushton & Juola-Rushton (2008) who go one step further in saying these adults support the brain development not only by their interactions and encouraging the children around them to discover and use autonomy, but also that this happens in a well-planned environment. Processes such as executive functioning thrive and develop in discovery-based environments such as that of the Montessori, Vygotsky or Piagetian approach (Alle-Herndon & Killingsworth, 2018). This places importance on the adult and the environment working together to create opportunities to develop the child's brain. Panksepp (2008) states that the genes in the brain change and modify as a result of the environment and its influences. This allows the cells to do different jobs and adapt accordingly. The brain's plasticity during early childhood means it is sensitive to environmental influences (Kapengut & Noble, 2020) and this plays a critical role in the formation amongst the neurons (Twardosz, 2012).

It has been reported many times how adult scaffolded play is important to the developing child; however, it has not often been directly linked with the specifics of the brain. Scaffolded play helps to develop what is termed proactive control. This means the neural mechanisms in the prefrontal cortex (PFC) uses the environment to take clues from to help the brain decide what may happen next (Hassinger-Das et al, 2017). Should this be the case, it would suggest an importance for the adults around developing children to be trained to recognise and understand how to create a responsive environment tailored to the different stages of play and to stimulate different areas of the brain.

Not only is it important to stimulate the areas of the brain, but also the generation of neurotransmitters too. A neurotransmitter is a chemical substance made by a neuron to transmit messages (Britannica, n.d). Dopamine is one such example. Dopamine creates a sense of wellbeing and enables a person to feel pleasure. Rushton et al (2010) claim that

creating excitement and novelty within a learning environment enables the generation of dopamine and that generating emotions (which are neurotransmitters plus hormones) helps to drive attention, which in turn, drives learning. They go on to suggest that in environments that are more teacher-directed with less emphasis on child led learning, the children feel less able to express themselves and this may create a stimulation of other, less desirable hormones such as cortisol (the stress hormone), having the opposite effect and decreasing the learning. With studies suggesting that stress changes the structure of the brain (Frost, 1998) and the executive functioning (Allee-Herndon & Killingsworth, 2018), it is important to try and regulate this in a learning environment. This link to stress is also supported by the study by the LEGO foundation (Lui & LEGO, 2017) whereby their results showed a decrease in neural activity in the specific part of the brain designed for stress regulation (amygdala) when their participants were actively engaged in tasks. The adult role is therefore a complex one where scaffolding and generating opportunities for learning through a stimulating environment is important, but the nature of the adult interaction needs careful attention too, with much adult direction potentially inhibiting development.

Another area in which the adult role shows significant impact on a child's brain development is in language acquisition and social interaction. Conversation is important for the development of the brain (Rushton & Larkin, 2001). A child's interactions with adults from birth help to build strong neural foundations in specific regions known for basic functional systems such as vision and language (Lui & LEGO, 2017). It is through talking and exchanging social connections with their children that parents can strengthen the neural pathways that are vital for the development of language (Frost, 1998). Kapengut & Noble (2020) support this view referring to the connectivity in the brain's white matter being stronger and more-coherent when there have been a higher number of adult-child conversational interactions. This was also the case for the children who participated in the study of gray matter with conversational turn taking, which showed those children who had more interactions presenting a significantly greater surface area in language-related brain regions (Kapengut & Noble, 2020). This suggests the importance of naming games, turn taking and speech related play with children.

***Brain Regions***

Having looked at the types of play, the tools used to measure the brain, and the role that the adults and environment play in influencing development, we can now take a look at the specifics of the brain and what happens where**.**

As previously stated, the architecture of the brain is established in the early years through a mix of genetic influences, environmental conditions and everyday experiences (Leisman, et al 2015; DiPietro, 2000). When a child is born, they are unable to sit, stand or walk and they rely on movements such as sucking or grasping, which are termed primitive reflexes. As the child grows, these primitive actions are replaced by more complex neural pathways as the brain accommodates new stimuli (Frost, 1998, Kapengut & Noble, 2020, Panksepp, 2007). This is also known as hard and soft wiring of the brain. A child's brain is hardwired through evolution, exerting behaviours such as breathing, reflexes and circulation. Individual brains are also softwired to adapt in response to stimuli, thus creating new neurological networks (Rushton & Larkin, 2001; Rushton et al, 2010). Experiences change the brain

(DiPietro, 2000; Frost, 1998). This happens with new dendrites forming and “hooking” new information. As a result of this process, we can assume that an enhanced environment increases cell weight and this new branching of the dendrites (Rushton & Larkin, 2001, Pg 29). Therefore, by creating social environments where children can play and interact, the urge to play is fulfilled and the social influences build socially functional minds.

It has been suggested that the age range where rapid development of cortical structure and function is between birth – three years old. DiPietro (2000) proposes that the learning and development a child embarks upon throughout childhood is a process to eliminate and maintain neuron associations, with Rushton et al (2010) adding that this time is also a time to develop new ones. This is done through play activities and experiences. In a recent gene expression analysis, results indicated that activity in a third of the total genes analysed in specific regions (frontal and posterior cortical) were significantly modified by play (Panksepp, 2007). Animal studies have supported this view of play affecting the neurological make-up of the brain, identifying rats that have deficiencies in the medial prefrontal cortex when raised without social play (fletcher et al, 2011). An increase in growth factors such as BDNF (brain-derived neurotropic factor) has been detected during social play with rats (Panksepp, 2007) and studies also show how play induces neural plasticity in areas of the brain involved in sensorimotor processing and the medial prefrontal cortex (which is known to control the social behaviours of animals) (Neale et al, 2018).

There have, however, been studies on children and some conclusions can be drawn to support the animal studies on the brain’s responses to play activities. Bhatia et al (2015) conducted a study which imaged the brain during a letter perception task and the results showed activated regions of the brain known to have associations with reading. This was following practice with the child drawing the letters by hand. When the child located the letters and typed them on a keypad, the results were not the same, suggesting the need for physical responses to activities to activate those regions of the brain. Frost (1998) also recognises the importance of connecting repeated actions for neural development when he speaks about the motor cortex of the brain being strengthened by repeated motor activities. All these results from various studies show how a child’s cognitive ability have been enhanced as a direct result of play-type activities (Tachibana et al, 2012).

For adults to appreciate the importance of play in child development, an understanding of the cognitive links is vital. When a child engages in a learning/play experience, multiple areas of the brain are activated simultaneously (Ruston & Larkin, 2001). For example, if a child is playing in wet sand and proceeding to attempt to build a structure, this activity stimulates the motor cortex, the occipital lobe and the prefrontal lobe (Rushton et al, 2010). Suddenly, this simple play activity to the untrained eye has become a complex, cognitive development task which encourages increased growth of the synaptic connections in the brain (Ruston & Juola- Ruston, 2008)

## Conclusion

Looking back to our original research questions, the literature supports the idea of play affecting the brain development of a child. Play activates various regions of the brain and facilitates changes in the neural structures. Play experiences potentially determine the

wiring of a child's brain and facilitates the development and activation of interconnected processes which in turn, supports the capacity to learn.

We understand the importance the adult role and environment plays in child development, especially in the brain and accept that more extensive research needs to be undertaken to further understand the link between play activities and the brain.

We understand the need for using animal studies to try to better understand the workings of the human brain. We appreciate that human and animal models are not perfect parallels and that it has been suggested that animals' brains are not as vulnerable to environmental influences as children (Lui & LEGO, 2017). However, we also understand that play activities carried out by humans and animals prepare them for the skills they will need later in life. For example, animals learn how to survive during play whereas humans learn language and motor skills (Frost 1998). Although caution must be exercised when transferring findings from animal studies to human studies, current data does suggest that across species, play is potentially a neurobiological process of which can produce changes in the neural circuits (Neale, et al, 2018; Tachibana, et al, 2012).
With a focus in education on more academic skills, such as reading and writing, and a certain disregard for more physical education and the creative arts, Panksepp (2007) expresses concern that natural play functions are being stolen from children and being replaced with more regimented tasks.

Ultimately, more research is needed on this topic. Adults, educators, early years professionals, all need more support and training to better fulfil their role in facilitating child development and understand the importance of this role. This importance also needs to be recognised by policy makers to acknowledge the role of play in development children's brains.

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