1

INTRODUCTION & LITERATURE REVIEW

1.1 INTELLIGENCE

Intelligence is the ability to think, learn from experience, solve problems, and adapt to new situations. Intelligence is essential because it contributes to knowing about interest, attitude, and desire if knowledge and communication skills are responsible for a person's behavior. Researchers explained intelligence from different aspects. According to Boring in 1923, intelligence was categorized into three parts, i) based on ability to adjust to the environment, ii) based on ability to learn, and iii) ability to carry out abstract reasoning. Hence intelligence is an ability to adapt to one's surroundings (Jean Piaget 1953). However, in 1965 Robinson and Robinson referred to intelligence as a whole class of cognitive behaviors', reflecting an individual's capacity to solve a problem with insight, adapt himself to a new situation, think abstractive, and profit from his experiences. There are several definitions present in literature about intelligence. For example, in a 1921 symposium, the American psychologists' Lewis Terman and Edward L. Thorndike differed over the definition of intelligence, Terman stressing the ability to think abstractly and Thorndike emphasizing learning and the ability to give good responses to questions.

More recently, however, psychologists have generally agreed that adaptation to the environment is the key to understanding both what intelligence is and what it does. Such adaptation may occur in a variety of settings: a student in school learns the material he needs to know in order to do well in a course; a physician treating a patient with unfamiliar symptoms learns about the underlying disease, or an artist reworks a painting to convey a more coherent impression. For the most part, adaptation involves making a change in oneself to cope more effectively with the environment. However, it can also mean changing the environment or finding an entirely new one.

According to Sternberg, Wagner, Williams, and Horvath (1995), intelligence is defined as such knowledge, which allows individuals to achieve goals they personally value without any external help, also known as practical intelligence. It is believed that intelligence is a result of several cognitive processes, such as perception, learning, memory, reasoning, and problem-solving. There are mainly two subcategories of intelligence, such as emotional intelligence or social intelligence. This is quite under various controversies and still under debate as to whether they are traditional forms of intelligence (Salovey, 1990, Walker 1973) or not. They are generally thought to be distinct processes, though there is speculation that they tie more into traditional intelligence than previously suspected. Despite their use of the word 'Intelligence,' some terms may have little or nothing to do with the mentioned cognitive processes.

1.1.(a) Emotional Intelligence

Since the mid-nineties, emotional intelligence (EI) is probably one psychological construct that has received the greatest attention in both popular and academic literature. Practically and historically, a distinction is made between two conceptualizations of emotional intelligence, namely an ability emotional intelligence model and a trait emotional intelligence model (e.g., Matthews, Zeidner, & Roberts, 2007). The first model represents emotional intelligence as cognitive ability and can be measured by performance-based tests. It presented emotional intelligence as another valid type of intelligence. Based on this model, emotional intelligence was defined as emotional, cognitive ability, or information processing emotional intelligence (Salovey & Mayer, 1990). Based on this model, emotional intelligence was divided into four sections: first, emotional identification, perception and expression through verbal and nonverbal behavior, second emotional facilitation of thought, third emotional understanding, and fourth, emotional management in maintaining or changing emotions (Côte 2014).

The second model, the trait EI model, in this model, emotional intelligence is defined as an array of non-cognitive capabilities, competencies, and skills that influence one's ability to succeed in coping with environmental demands and pressures (Baron, 1997). This model explains emotional intelligence as abilities, i.e., emotion perception, combined with non-cognitive competencies, skills, and personality traits. The present model measures five broad factors and fifteen facets: (1) Intrapersonal (Self-Regard, Emotional Self Awareness, Assertiveness, Independence, and Self-Actualization), (2) Interpersonal (Empathy, Social Responsibility, and Interpersonal Relationship), (3) Stress Management (Stress Tolerance and Impulse Control), (4) Adaptability (Reality Testing, Flexibility, and Problem Solving), and (5) General Mood (Optimism and Happiness). Further, Goleman expanded this model in 1995 and referred to emotional intelligence as a set of learned competencies. Again, divided EI into mainly five clusters: self-awareness, self-regulation, motivation, empathy, and social skills.

Meta-analytic research (Van Rooy, Viswesvaran, & Pluta, 2005) demonstrated that these two models do not measure the same constructs. Measures based on the two models correlate only .14 with one another. Also, these two models had different correlates. The mixed model's emotional intelligence measures overlapped considerably with personality trait scores but not with cognitive ability. Conversely, emotional intelligence measures developed according to an emotional intelligence ability model correlated more with cognitive ability and less with personality. Other research has clarified that ability model measures correlate with verbal (crystallized) ability, with correlations typically between .30 and .40 (Mayer, Roberts, & Barsade, 2008). Hence, some have suggested that the term "emotional intelligence" should be replaced by the term "emotional knowledge" (Zeidner, Matthews, & Roberts, 2004). A further mixed emotional intelligence model (Mayer et al., 2008) showed conceptual and methodological problems.

First, its ambiguous definition and the mixed model's extensive content have been criticized (Landy, 2005; Locke, 2005; Matthews, Roberts, & Zeidner, 2004). The second criticism relates to the redundancy of the mixed model with Big Five personality traits. Nevertheless, the other several studies found incremental validity of the mixed model. That said, the ability model is not without limitations either. For example, a large scale examination of emotional intelligence, cognitive intelligence, and personality measures showed that emotion perception (as represented by measures of perception of emotions in faces and pictures) was the only branch out of the four branches of the ability model that could not be classified under established measures (Davies, Stankov, & Roberts, 1998). Also, the emotion perception construct has drawbacks as the construct does not seem to have generalizability across different measures (Gohm, 2004). That is, existing emotion perception measures correlate lowly among themselves (Roberts et al., 2006).

In comparing the findings from the ability and the trait models, a major methodological problem exists due to a method-construct confound resulting from the fact that the ability model is often measured using performance-based tests. In contrast, the trait model is often measured using self-reports. In order to advance the research on the comparison of ability and trait models of emotional intelligence (and also on the comparison of these models when applied to practical intelligence or social intelligence), rigorous designs that clearly stated that isolate construct and method variances are needed (Chan & Schmitt, 2005).

1.1. (b) Social Intelligence

Of all three, the practical, emotional, and social intelligence has the most extended history. The idea goes back to Thorndike (1920), who defined social intelligence as the ability to understand and manage men and women, boys and girls – to act wisely in human relations. As stated by Landy (2005), Thorndike did not build a theory of social intelligence. However, he used social intelligence to clarify that intelligence could manifest itself in different facets: abstract, mechanical, and social.

Early studies tried to distinguish social intelligence from academic intelligence (Hoepener & O'Sullivan, 1968; Keating, 1978). However, these research efforts were unsuccessful. The problem was that social intelligence measures did not correlate highly among themselves and that academic intelligence and social intelligence formed one factor. It was methodologically troublesome that both intelligences were measured with the same method of paper and pencil measures. The early research led to the conclusion that the putative domain of social intelligence lacks empirical coherency, at least as it is represented by the measures used here (Keating, 1978).

Later two advancements led to more optimism for this concept. The first was the distinction between *cognitive,* social intelligence (e.g., social perception or the ability to understand or decode verbal and nonverbal behaviors of other persons) and *behavioral,* social intelligence (effectiveness in social situations). Using this multidimensional definition of social intelligence and multiple measures (self, teacher, and peer ratings), Ford and Tisak (1983) distinguished social intelligence from academic intelligence. Also, social intelligence predicted social behavior better than academic intelligence (Marlowe, 1986). The second advancement was using multitrait-multimethod designs (and confirmatory factor analysis) to obtain separate and unconfounded estimates of trait and method variance (Jones & Day, 1997; Wong, Day, Maxwell, & Meara, 1995).

Further, more evidence showed the multidimensionality of social intelligence and academic intelligence could be explained. For example, a significant distinction between cognitive social intelligence and behavioral social intelligence has been confirmed (Wong et al., 1995). Similarly, a distinction is often made between fluid and crystallized social intelligence. The fluid form of social intelligence refers to social-cognitive flexibility (the ability to apply social knowledge in novel situations flexibly) or social inference. Conversely, a term such as social knowledge (knowledge of social etiquette, procedural and declarative social knowledge about social events) denotes the more crystallized component of social intelligence (Jones & Day, 1997).

Despite these common findings, the dimensions, definitions, and social intelligence measures still vary considerably across studies. Weis and Süss (2005) provided an excellent overview of the different facets of social intelligence that have been examined along these lines. This might form the basis for adopting a more uniform terminology in the description of social intelligence sub-dimensions. Interest in social intelligence has also known a renaissance under the general term of social effectiveness constructs. According to Ferris, Perrewé, and Douglas (2002), social effectiveness is a: broad, higher-order umbrella term, which groups several moderately related, yet conceptually-distinctive, manifestations of social understanding and competence. Examples are social competence, self-monitoring, emotional intelligence, social skill, practical intelligence, etcetera. The value of social skills has been scrutinized significantly in the literature. Similar to social intelligence, social skills are posited to have a cognitive component (interpersonal perceptiveness) and a behavioral component (behavioral flexibility, Riggio, 1986; Schneider, Ackerman, & Kanfer, 1996). Another exciting framework of social skills was proposed by Klein, DeRouin, and Salas (2006). They distinguished among ten social skills, which they more parsimoniously grouped under two meta social skills (communication and relationship building).

A key difference between social skills and personality traits is that the former is learned (an ability), whereas the latter is relatively stable. Research has also found that they are only moderately (.20) correlated (Ferris, Witt, & Hochwarter, 2001). However, both constructs also relate to social skills enabled personality traits to show their effects (Ferris et al., 2001; Hogan & Shelton, 1998). Research has confirmed that social skills moderate personality traits' effects on job performance (Witt & Ferris, 2003). Social skills were also found to directly affect managerial job performance, although personality and cognitive ability were not controlled for most studies (Semadar, Robins, & Ferris, 2006).

This section of **chapter 1** outlined the practical, social, and emotional intelligence. This section highlights that these three constructs share remarkable similarities. Specifically, we see at least three parallels. The current research state indicates that such efforts have been undertaken for social and emotional intelligence (ability model). Still, more rigorous construct validation studies are needed.

Second, the conceptualizations of these three constructs have salient parallels. Each of these three constructs has various definitions, they are multidimensional, and there exists a debate about their different dimensions.

Third, for each of these constructs, there are conceptual differences between the three constructs. Although the present literature showed that these three constructs have overlapped, making at least some subtle distinctions is possible.

As intelligence, emotional intelligence, and social intelligence aggregate different abilities to adjust and adapt socially in an impressive way in the surrounding environment and effectively navigate and negotiate complex social relationships, social intelligence is required. Like intelligence, social intelligence also varies from individual to individual; most people are average, a few are very high, and a few are very dull. At attained in the same individual at different ages and usually stabilizes at adolescence and continued till lifelong. According to psychologist Nicholas Humphrey, social intelligence, rather than quantitative intelligence, defines humans. Social intelligence is closely related to social cognition. This is explained further in **section 1.2**.

1.2 SOCIAL COGNITION

Social cognition is the process by which social information, mostly encoding, storage, retrieval, and application to social situations, occurs or the group of functions related to adequately perceiving and processing social signals (consciously or unconsciously). This process's outcome depends on the interpretation of social signals emitted during the encounter, including language, facial expressions, and body gestures. Social cognition develops at a very early stage of life. As children grow, they become more aware of their own feelings, thoughts, motives, and others' emotions and mental states. Children adapt very easily to understanding others' feelings, respond in social situations, engage in prosocial environments, and receive others' perspectives.

There are many theories about how social cognition develops in an individual, but psychologist Jean Piaget's works are very popular. He mainly focused on the cognitive development of a child in different stages. According to Piaget, during the earliest stages of development, the children are very egocentric. Every child sees the outer world from their own perspective and struggles equally to think about how others view the world. As they grow, they start taking others' perspectives about how others think and behave in social situations. Along with this, one more development occurs that is starting of social cognition in the form of the theory of mind (TOM). The TOM is essential as well as critical; it makes someone able to consider the thoughts, beliefs, feelings, desires, and experiences that other person may have.

In summary, social cognition is referred to different psychological processes that make a person a part of a social group and help establish communication with the world. When an individual connects with the world, various psychological processes help in two-way interaction with social signals. However, if an individual faces difficulty doing so, it is known as lack of social cognition or social cognitive impairment.

1.3 SOCIAL COGNITION DEFICIT (SCD)

Social cognitive deficit or Impairment in its severe form reflects Autism Spectrum Disorder (ASD). In contrast, in individuals with autistic traits or individuals with a family history of ASD, it may reflect in a mild form. Usually, social impairment is evident in unusual or inappropriate body language, gestures, and facial expressions (e.g., avoiding eye contact or using facial expressions that do not match with what he or she is saying), lack of interest in other people, or in sharing interests or achievements, feels difficulty in approaching others or in pursuing social interaction; feels detached; prefers to be alone, difficulty understanding other people's feelings, reactions and nonverbal cues, resistance to being touched, difficulty or failure to make friends with same age people.

1.3.1 Prevalence

According to Shuang Qiu and colleagues' meta-analysis, in 2019 for Asian countries, among 12 2,195,497, the overall prevalence rate is 0.36%, with males' ratio to females (4: 1), i.e., Male 0.45% and female 0.18%. Recent Statistics' of the year 2020 by the Centers for Disease Control and Prevention estimated that around 222 per 10,000 children in the United States had autism spectrum disorder, one of the highest prevalence rates in the world. 3.63 percent of boys aged 3 to 17 years had autism spectrum disorder compared to 1.25 percent of girls. According to an observational study published by Arora NK and colleagues in 2018, about 1 in 100 children in India under age 10 has autism, and nearly 1 in 8 has at least one neurodevelopment condition. Therapies can help children with an autism spectrum disorder in developing social, communication, and self-care skills that can help them better live with their disorder. Many children with autism spectrum disorder also suffer from other disorders such as attention deficit hyperactivity disorder, a learning disability, or an intellectual disability.

1.3.2 Social Cognitive Impairment Literature

People with social cognition display a set of neurocognitive processes related to understanding, recognition, and processing (Adolphs, 2009; Ochsner, 2008; Penn, Corrigan, Bentall, Racenstein & Newman, 1997). Based on these neurocognitive processes, researchers can predict other people's intentions, feelings, and thoughts. Among these processes, human behavior is specific and unique with the influence of cultural environment on social cognition (Aronson, E.; Wilson, T; Akert, R. (2010)). Social information processing can be differentiated into (e.g., metalizing, social knowledge, emotion recognition). This approach concerns majorly processes involving perception, judgment, and memory of social stimuli; the effects of social and affective factors on information processing; and the behavioral and interpersonal consequences of cognitive processes. According to this view, social cognition is a level of analysis that aims to understand others and their intentions; that carried out social interactions (Green et al., 2008). Indeed, the lack of social-cognitive skills in human life has prompted some observers to witness that social cognition has the primary focus of evolutionary change in humans (Kamil, 2004; Tomasello, 1999).

Researchers in the neurosciences have focused their attention on understanding how the brain gives rise to these remarkable social abilities. They proved that social cognition exists in the human brain with a subset of general cognitive processes (Adolphs, 1999; 2003; Blakemore, Winston & Frith, 2004). Various aspects of social cognition have been listed below (**Table 1.1**):

Table 1.1 Showing various important aspect of Social cognition

Important aspects of Social cognition
• Recognize the difference between self and others
• Emotional recognition of others
• Collaboration
• Sharing episodic memory
• Theory of Mind
• Perspective making
• Empathy

Further based on these abilities, Tomasello (Tomasello 1999) proved that human life is different from individuals who have a selective social impairment, such as in autism or after specific brain damage. Indeed, the importance of human sociability both to everyday life and the cultural differences in the world has motivated some researchers to argue that social cognition may have been one of the primary human evolution engines. For example, Tomasello (1999) has argued convincingly that what sets Homo sapiens apart from other primates is the ability that represents the mind of beings. Based on his argument, one can predict the importance of sociability and various cognitive processes (i.e., thinking and interacting with other individuals) to human life.

In 1996, Hornak studied Phineas Gage's case, whose behavior was reported to have changed after an accident with damaged frontal lobes. He found a strong relationship between brain function and social cognition. Other neuropsychological studies give supporting evidence about those brain injuries affect social cognitive processes. Based on the evidence, one can say that frontal lobes damage can affect emotional responses to social stimuli (Harmon-Jones, E.; Winkielman, P.,2007; Damasio, A.R., 1994; Hornak, J.; Rolls, E.T.; Wade, D., 1996), and performance on theory of mind tasks (Stone, V.E.; Baron-Cohen, S.; Knight, R.T., 1998; Brunet, E.; Sarfati, Y.; Hardy-Bayle, MC.; Decety, J., 2000), In the temporal lobe, damage to the fusiform gyrus can lead to the inability to recognize faces. Brain areas that take part in social cognition (Billeke, P., & Aboitiz, F. (2013) are shown in **Figure 1.1**

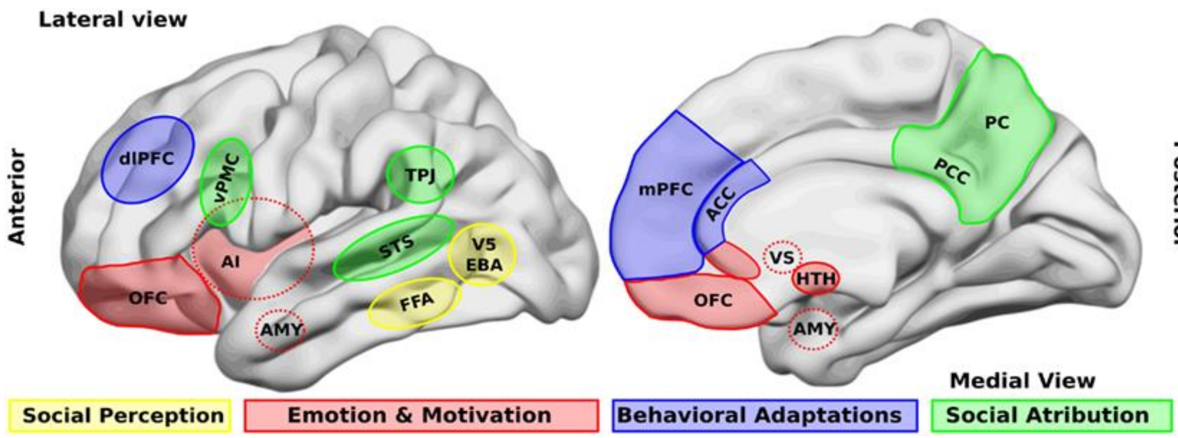

Figure 1.1: Brain areas that participate in social processing. A simple classification of brain areas involved in social processing differentiates regions that participate in four related processes. The first is the perception of basic social stimuli, such as biological motions (V5), part of the body (extra-striate body area, EBA), and faces (fusiform face area, FFA). Another process includes emotional and motivational appraisal, where the amygdala (AMY), the anterior insula (AI), the subgenual and perigenual anterior cingulate cortex (ACC), as well as the orbitofrontal cortex (OFC) participate. These cortical structures are in interaction with subcortical structures as the ventral striatum (VS) and the hypothalamus (HTH). These structures interact with other regions that participate in the goal-directed, adaptive behaviors and the categorization processes, such as the dorsolateral and the medial prefrontal cortex (dlPFC, mPFC) and the ACC. Finally, for social attribution, areas like the ventral premotor cortex (vPMC), the superior temporal sulcus (STS), the AI, the posterior cingulate cortex (PCC), and the precuneus (PC) participate in more automatic, bottom-up inferences of other people's mental states; whereas structures like the mPFC and the temporo-parietal junction (TPJ) are involved in the more cognitive theory of mind skills. (Billeke, P., & Aboitiz, F. (2013).

Impairment in social cognition processes results from damage to the brain areas or their connections in social processing. The areas responsible for cognitive functioning in the brain should be well understood because a minute dysfunction in one structure of the brain or damage to white-grey matter (Kennedy, 2012) can disrupt cognitive processes' at the functional level. The resulting process can be seen with ToM (Schurz, 2014), empathy (Bernhardt, 2012), social perception (Yang, 2015), and social behavior (Szczepanski, 2014). Several other studies gave evidence that different brain damage areas can disrupt different types of cognitive processes, i.e., damage to the orbitofrontal cortex (OFC) is responsible for disinherited behaviors, such as socially inappropriate and compulsive behavior (Beer, 2006). It is believed that the association of OFC is linked to decision-making (Viskontas, 2007). Damage to the anterior cingulate cortex (ACC) is linked with behavioral disturbances disturbance in motivational and emotional behavior (Szczepanski, 2014). Any disturbance at the temporoparietal junction may result in one's inability to view a situation from another person's perspective, leading to abnormal moral reasoning (Samson 2004, Young 2010).

The main cause of these disturbances is the temporoparietal junction that plays a central role in integrating social, attentional, memory, and language processing to build a social context for behavior (Carter 2013). In clinical or psychopathological contexts, social impairment is common and contributes a great deal to the burden of mental illness or disability. This has been linked to low quality of life, mental health problems, unemployment, and loneliness (Philips 2010, Brüne 2007, Cacioppo 2014). In April 2008, the American Psychiatric Association's (APA) DSM-5 Task Force began work proposing revisions to the criteria for the disorders referred to in DSM-IV as Delirium, Dementia, Amnestic and Other Cognitive Disorders (APA, 2000, Ganguli 2011). Based on the given evidence, the disorders with social cognitive impairment were categorized as shown in **Table 1.2**.

Table 1.2. Showing categorization of disorders with social cognitive impairment (APA, 2000)

Disorders with social cognitive impairment			
Psychiatric disorders	**Developmental disorders**	**Neurodegenerative disorders**	**Acute brain damage**
Schizophrenia	**Autism spectrum disorder**	Frontotemporal dementia	Traumatic brain injury
Bipolar disorder	Fragile X syndrome	Alzheimer disease	Stroke
Antisocial personality disorder	Williams syndrome	Amyotrophic lateral sclerosis	
Major depressive disorder	Angelman syndrome	Parkinson disease	
Post-traumatic stress disorder	Prader–Willi syndrome	Huntington disease	
Social phobia	Turner syndrome	Progressive supranuclear palsy	
Anorexia nervosa	Rett syndrome	Corticobasal degeneration	
Personality disorders (example: borderline,anti-social,narcissistic)	Attention deficit hyperactivity disorder Severe conduct disorder Fetal alcohol syndrome	Multiple sclerosis	

1.4 BROADER AUTISM PHENOTYPE CONCEPT

Social impairment may be the most complex and impenetrable core challenge facing children with autism (Kasari, C. 2012, Wing 1981). According to a recent frame of reference, social impairment is the main symptom of autism. Majorly autism spectrum disorder (ASD) is described as impairment in three areas: social communication, social interaction, and restrictive or repetitive behavior patterns (American Psychiatric Association, 2013). A person with these symptoms shows the difficulty in integrating with their peers in social situations or shows less interest.

In one way, we can say that ASD shows impairment in social functioning with various effects. It may vary from mild to severe. While on the other hand, traits of ASD are seen in the general population among undiagnosed people (Baron-Cohen et al., 2001; Kanne et al., 2009) and maybe especially prevalent among relatives of individuals with ASD, as termed broad autism phenotype (BAP) (Bishop et al., 2004; Hurley et al., 2007). Several extensive population studies have shown that social impairment is continuous in epidemiologic samples, where autism appears at negative extreme and typical developed (TD) individuals at other ends (Constantino & Todd, 2003). Indeed, researchers suggest that individuals with ASD are more likely than the general population to be good at science, technology, engineering, and maths (STEM) (Moore 2006; Morton 2001; Safer 2012).

This path from a lack of social skill to good science and technology fields makes this study more interesting. It has been believed that people with excellent skills in the STEM field show similar scores on social impairment than autistics. Most of them showed scores above than threshold on a typical screening tool. Such population is also named as subclinical population (Baron-Cohen et al., 2001). The people who are near the threshold are also lacking in social interaction level. However, there is still a debate going on that the traits of autism lying on a continuum of the population from clinical (autistic) to subclinical to (normal) typically developed.

1.5 AUTISM AND SOCIAL COGNITIVE DEFICITS

Autism is a developmental disorder that is characterized by social and communication impairment. In autism, impaired social interaction is an intuitive ability to understand thoughts and feelings to others' theory of mind' or 'mentalizing' in the social environment (Baron-Cohen et al., 1985, Mortan 1995). Schizophrenia is also an example of this kind of deficit (Bentall et al., 2001). Researchers proposed another domain of deficit in social cognition, i.e., empathy (Blair et al., 1996). These domains marked difficulties in behavior, social interaction, communication, and sensory sensitivities (Landa, 2008; Dawson, 2008; Mundy, 2003; Neuhaus, Beauchaine,& Bernier,2010). These characteristics are defined in **Table 1.3**. Among these characteristics, some are common; others are typical of the disability. Some theories can help an individual understand the complexities associated with social cognition in autism spectrum disorder. The social impairment is explained in terms of poor performance in various areas, also known as cognitive theories of Autism Spectrum Disorders (ASD), as detailed below:

Table 1.3. Characteristics of Autism Spectrum Disorder

Behavioral	Social Interaction	Communication
unusually intense or focused interests	• limited use and understanding of non-verbal communication such as eye gaze, facial expression, and gesture	• delayed language development
• stereotyped and repetitive body movements such as hand flapping and spinning	• difficulties forming and sustaining friendships	• difficulties initiating and sustaining conversations
• repetitive use of objects such as repeatedly switching lights on and off or lining up toys	• lack of seeking to share enjoyment, interests, and activities with other people	• stereotyped and repetitive use of language such as repeating phrases from television
• insistence on sticking to routines such as traveling the same route home each day and doing things in the same order every time	• difficulties with social and emotional responsiveness	
• unusual sensory interests such as sniffing objects or staring intently at moving objects		
• sensory sensitivities, including avoidance of everyday sounds and textures such as hair dryers, vacuum cleaners, and sand		

1.5.1 Theory of mind

According to Baron and Cohen, ' Theory of mind' is the ability to understand other people's thoughts and feelings (Baron-Cohen, Leslie &Frith, 1985). This theory explains that people with ASD have lacked the ability to interpret the actions of others. Someone with challenges in theory of mind, i.e., may face a confusing state while performing in society. This theory is supported by atypical responses of children with autism while performed Sally–Anne test for reasoning about others' motivations (Baron-Cohen S. 2009). Although many studies say that autistic have no impairment in understanding others' basic intentions or goals, they showed impairment in understanding complex social situations, i.e., a problem in understanding others' emotions or considering others' viewpoints (Hamilton AF 2009).

1.5.2 Emotional Processing

The capacity to feel or understand another person's desire and emotions from their own experiences is known as an individual's emotional processing capacity. This is also known as the capacity to put oneself in another position. A broad range of emotional states is known as empathy (Bellet 1991). Types of empathy include cognitive, emotional, and somatic empathy (Rothschild 2006, Hannah 2019). If we talk about emotional processing in the clinical context, it was found that autism spectrum disorder lacks sharing enjoyment, interests, emotions, and achievements with different individuals and a lack of emotional exchange. In 1943 Kanner gave evidence to the presence of emotional impairments and characterized the patients as indifferent to other people, self-absorbed, emotionally cold, distanced, and retracted. However, these emotional impairments were shifted to the later years' background and considered part of the core social deficits (Ritvo and Freeman, 1977; Rutter, 1978; Denckla, 1986; Fein et al., 1986).

1.5.3 The mirror neuron system (MNS) and Mu Rhythm

The MNS-Mu hypotheses suggest that Mu rhythm is responsible for the development of imitation at the very early stage of life. Further, it plays a crucial role in the development, i.e., motor skills and interactive social behavior (Marshall, 2011). The mirror neuron system consists of a class of neurons that fires and produces some electrical activity. This activity can record by EEG waveforms the particularly Mu rhythm originating from the mirror neuron area. Mu waves are considered a variant of alpha waves. In the brain, mu wave activity mainly occurs in the sensory-motor cortex with oscillates at a frequency ranging from 8 to 13 Hertz (Hz). Empirical support for the role of MNS and associated mu wave comes from the studies showing decreased mu wave activity in autistic patient and individual with autism trait only when they are performing physical actions, not when they are watching others (R. Bernier, G. Dawson, S. Webb & M. Murias,2007).

1.5.3(a) The mirror neuron system (MNS) theory

MNS is responsible for all social cognitive behavior related to observation and imitation, allowing one to understand others' goals and actions (Williams JH, 2008; Dinstein, 2008). The disrupted mirror neuron activity with imitation results in autism's core features of social impairment and communication difficulties. The MNS gets activated when an animal performs an action or observes another animal perform the same action (Iacoboni, 2006). No studies say that structural damage to MNS regions of individuals with ASD causes delayed imitation (Frith, 2003). However, it has also been seen that autism is also due to damage in circuits outside the MNS, and MNS does not support the normal function of an autistic related to imitation tasks (Hamilton AF, 2008). The mirror neuron system consists of a class of neurons that fires and produces some electrical activity. This activity can be recorded by EEG waveforms the particularly Mu rhythm originating from the mirror neuron area. Mu rhythm is responsible for the development of imitation at a very early stage of life. Further, it plays a critical role in the development, i.e., motor skills and interactive social behavior (Marshall, 2011).

1.5.4 Executive Dysfunction in autism

There is a difference between the theory of mind and executive functioning and theory of mind, and executive functions are domain free while the theory of mind is domain-specific. Studies available in history say that theory of mind is related to brain injury directly, but executive functioning does not. According to a study by Baddeley in 1988, lack of impulse control or problem in switching the attention was named Dys-executive Syndrome (DES, Baddeley & Wilson, 1988). The above statements can be summarized better, i.e., a problem with the theory of mind necessarily not responsible for executive dysfunctions. Hence, autism could be explained as the EF deficit (Ozono V et al., 1991a, Shallice and Burgess (1991). However, shared sites in the brain-related to the theory of mind and executive functions showed impairment in the frontal cortex (Shallice, 2001; Stone, Baron-Cohen, & Knight, 1998; Stuss, Gallup, & Alexander, 2001, Apperly, Samson, & Humphreys, 2005).

1.5.5 Weak central coherence theory

Central Coherence is the ability to immediately get a general idea of the current situation (Frith, 1989). Weak Central Coherence Theory (WCC, Frith, 1989, 2003; Frith & Happé, 1994; Happé, 1999) is not domain specific; it may include both social and non-social features of autism. According to this theory Autistic person tries to focus on every detail of a situation compared to seeing it as a whole. However, Weak Central Coherence Theory may lead to confusion in getting details of domain-general.

1.6 Mu RHYTHM

The mu rhythm is a specific electrical activity in electroencephalogram (EEG) pattern, where Mu stands for motor; this rhythm is related to the brain's functions (Fisch, 1999, Enticott 2010, Muthukumaraswamy 2004, Perry 2009). It is of frequency in a normal population (7.5 – 12.5 Hz), found over the Sensory-motor cortex (Gastuat 1954, Perry 2009, Amzica et al., 2010). Since 1938, there is no clear evidence that mu rhythm underlies physiological and pathological features (Jasper, 1938). Fischer first explained the epileptiform spikes of four basic waveforms (Fisch, 1962, Kirschfeld K 2005). After 1938, each variation related to these four basic waveforms was coined as "not normal." A study by Zifkin has also reported this trend's consistency (Zifkin, 2009). Mu waves are arch shape pattern in the rolandic area as precentral alpha rhythm has a frequency of 7-11 Hz, this frequency band generally lies in the alpha frequency band (8-12 Hz) (Gastaut 1954, Okada 1992, Niedermeyer & da Silva, 2005, Perry et al., 2009). One recent study by Nombela and his colleagues defined normal mu rhythm with eye open and closed situations. (**Figure 1.2**) (Nombela C, Nombela M, 2013).

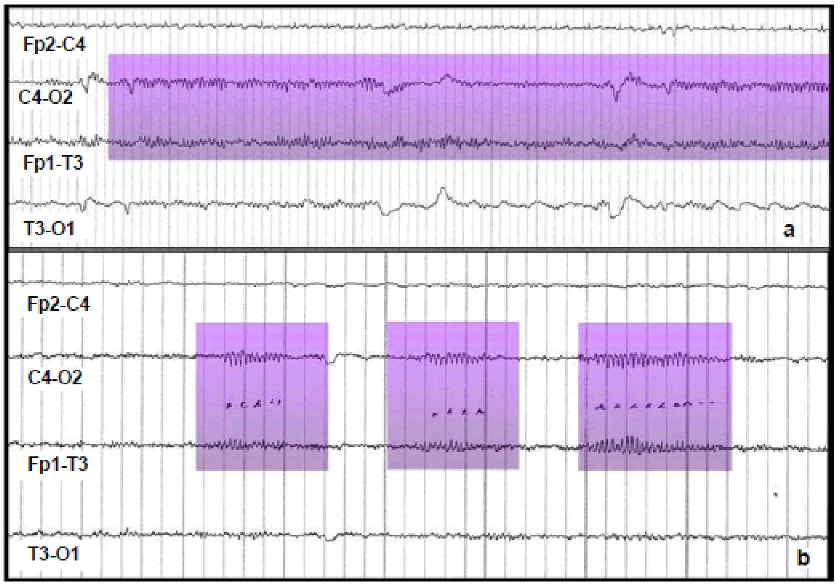

Figure 1.2: Example of mu rhythm pattern: a) continuous mu rhythm (mu status), b) spike-wave discharge (Nombela C, Nombela M, 2013)

Mu waves have amplitude generally low to medium and comparable to that of the alpha rhythm. Mu is derived from the brain wave pattern's similarity to the letter 'μ' (Urakaime, 1992). As Mu wave is found over the motor cortex and sensory-motor area, it attenuates contralateral extremity movement with the adjacent cortex, followed by the thought of a contralateral movement or tactile stimulation of a contralateral limb. On the other hand, the alpha wave does not react to the eye's opening and closing (Kleber, 2005). Following the description of mu wave in infants can be detected at the age of four to six months, at a range of 5.4 Hz (Churchland, 2011 and Nyström, 2011). It attains its peak frequency of 7.5 Hz (Nyström, 2011) at the age of two and attains a stable frequency of 8-13 Hz with age to get into adulthood (Smith, 1939, Smith, 1941, Hagne 1972, Stroganona 1999, Nyström, 2011, Marshall et al. 2011, and Berchicci et al. 2011). Pineda studied and concluded that these frequencies were measured around the central sulcus within the Rolandic cortex (Pineda, 2005). In literature, the Mu waveform was initially named the Rolandic or central alpha rhythm. It was associated with the sensorimotor cortex around the central sulcus and the same frequency range as the alpha wave (Fisch, 1999, Berchicci 2011). According to Fisch, the mu rhythm is more common in younger adults, but the literature suggests that variance in the prevalence rates is more commonly seen between the ages of 11-20 years (Niedermeyer, 1997). Reports from history related to the incidence of mu in the population, ranging from less than 10% up to 19% (e.g., Cochin, Barthelemy, Lejeune, Niedermeyer, 1997; Tyner et al., 1983).

1.6.1 Associated conditions with Mu rhythm and attenuation

Earlier it has been established that generally, the Mu wave was not pertaining to diseases. However, nowadays, it is assumed to be connected with a certain level of neuronal hyperexcitability (Okada, 1992). A group of researchers believes that excess mu waves are found in a diseased population, i.e., ASD. This excess of Mu leads to various motor functions, attention, and various cognitive processes. This hypothesis came up with evidence that proved the coexistence of mu rhythms with psychopathological symptoms such as anxiety, aggressiveness, hyperactivity, and several other psychosomatic features (Urakami,1992). Neurons fire together in synchrony when an individual is at rest, but during action observation and imagining in the same task, underlying neurons come in action and result in mu rhythm attenuation. Kind of attenuation pattern in mu rhythm has been continuously found in adults and children (Babiloni et al. 2003, Cochin et al. 2001, Lepage et al. 2006, Muthukumaraswamy 2004, Martineau 2003). As occipital alpha represents the visual center's idling, mu rhythm is related to somatosensory processes. In the sensory system presence of mu, rhythm showed decreased neural processing (Fisch, 1999). During eye-opening posterior alpha, the rhythm becomes desynchronized and attenuated, and mu rhythm desynchronizes and attenuates with movement (Pineda, 2005; Niedermeyer, 1997).

It proves that mu rhythm reflects a state of reduced motor cortex activity. Several studies support the fact that mu blocking takes place under specific task conditions in humans. That is called attenuation or amplitude decrease of a particular EEG rhythm, such as the alpha rhythm (Tyner et al., 1983). Many studies say that changes have been noticed over the sensory-motor cortex during action observation or imaging the same situation (Muthukumaraswamy 2004, Ohno 2011, Braadbaart 2013). One of the most recent studies has shown changes in EEG patterns, specifically during observation, and concluded that action observation would be more effective than imagining the same situation in case of abnormal participants (Pfurtscheller 2006, Proverbio, 2012, Kim 2014).

When we talk about the mechanism of attenuations over the sensory-motor area, it has been noticed that brain waves are strongly inhibited during the execution of an observable movement, such as prehension (Jeannerod 1995, Hari 1998, Castiello 2005), as well as during (Decety 1997, Jarvelainen 2004, Nishitani 2000, Vogt 2007, Nystrom 2008) or imagination of goal-directed action (Grafton1996, Molnar 2006). A study by Fecteau et al. reported modulation of EEG signals recorded over the sensorimotor area in a 36-month-old child undergoing intracranial surgery for intractable epilepsy. They observed the spectral power's attenuation in the mu rhythm frequency band while the child was drawing with her right hand versus watching an experimenter perform a similar movement. Fecteau et al. interpreted this mu rhythm attenuation as a reflection of sensorimotor processing in the frontoparietal network (Fecteau 2004).

Further, in 2008, VanElk et al. measured the spectral power to investigate the effect of motor experience on motor resonance during observation in both mu and beta frequency bands in EEG signals recorded in twelve 14- to 16-month-old toddlers. They found a stronger motor resonance for observing actions that were already present in the infants' motor repertoire and stronger mu and beta desynchronizations concerning the infant's natural crawling experience (Van et al. 2008). Nystrom in 2008 first showed that the observation of others' goal-directed actions is identifiable by mu rhythm modulations in infants as young as six months of age (Nystrom 2008).

1.7 NEUROFEEDBACK TECHNIQUE

Neurofeedback is part of a wide group of biofeedback applications, all of which have the goal of facilitating the self-regulation of physiological functions to normalize them in clinical populations or optimize them in healthy subjects. Neurofeedback is used as a tool for 'normalization,' also as a performance-enhancer for a healthy population (Gruzelier, Egner, & Vernon, 2006). The core idea is to identify associations between particular patterns of cortical activity and specific states or aspects of behavior that are classified as 'optimal.' One can attempt to train an individual to enhance performance by mirroring the pattern of cortical activity seen during such optimal states. Literature also showed different targeted aims for enhancing the performance from the earlier level of arousal, attention, and motivation, etcetera. (Landers, 1985; Norris & Currieri, 1999; Wilson & Gunkelman, 2001). Compared to intervention in a healthy population, EEG biofeedback for the clinical population is frequent and diverse.

1.7.1 History and Development of NFT

Neurofeedback or EEG biofeedback is a computerized technique that entails training individuals to actively control and change their neural activation pattern by viewing the brainwaves they emit a few milliseconds after they occur. EEG signals from specific cortical areas are converted to a visual or auditory representation that participants receive and subsequently attempt to regulate through training. This training could follow classical conditioning or operant conditioning learning paradigm.

This whole area of individual assessment, intervention, and self-management through NFT has a base in the development in the measurement of brain waves. The first human EEG recordings were captured in the early 20th century by Hans Berger, who observed this phenomenon as a fluctuating, wave-like signal (Berger, 1929). Even with the relatively primitive instrumentation available at the time, Berger was able to identify a very regular pattern of wave activity oscillating at 8-12 cycles per second (Hz). This waveform has been dubbed 'alpha,' and since Berger's time, researchers have identified several brain 'states' that correlate with distinct mental states and that are defined by increased power in specific frequency bands (e.g., Delta: Knyazev, 2012; Theta: Ponjavic-Conte, Dowdall, Hambrook, Luczak, & Tata, 2012; SMR: Sterman, Wyrwicka& Roth, 1969; Beta: Perlis, Merica, Smith & Giles, 2001; Gamma: Fitzgibbon, Pope, Mackenzie, Clark & Willoughby, 2004).

In the 1960s, Joseph Kamiya was the first to investigate the effects of providing individuals with immediate feedback about their brainwave activity. This idea followed the observation by Berger himself that the alpha wave's occurrence coincides with the calm and peaceful state. Hence, Kamiya'sresearch involved training these individuals to identify the experience of an 'alpha state,' where alpha waves dominate the composition of the EEG. Kamiya's earliest publication of this research (1968) describes two groundbreaking investigations into this area.

Soon afterward, a significant revelation about the therapeutic effects of neurofeedback training (NFT) emerged. Sterman, Wyrwicka, and Roth (1969) subjected cats to monomethylhydrazine (MMH) as part of a United States Air Force-sponsored research project investigating rocket fuels' toxic effects. Some of the cats had coincidentally been a part of a recent and unrelated study involving neurofeedback training of the SMR. Although MMH induced seizures in most cats at a specific dosage, it was unexpectedly (and very interestingly) observed in this study that the SMR-trained cats had significant resistance to the chemical's convulsive effects. Sterman's research group performed several follow-up studies to explore the training effect, and in 1974 demonstrated the efficacy of SMR neurofeedback training towards preventing seizures in epileptic humans (Sterman, Macdonald, & Stone, 1974).

Although studies into NFT date back to the 1960s, it is only with recent advances in the capabilities of computer technologies that such research has begun to make headway. In the past decade, researchers have probed the effects of NFT on a wide range of human activities. This research can be further delineated into studies relating to clinical and healthy populations, all of which are relevant to clinical and educational research (Menzies, 2014).

Dating back to the history of neurofeedback, the research could be categorized into two populations: clinical population, where the aim is to normalize their symptoms, and healthy population. Here the aim is to optimize the functioning or to achieve peak performance.

1.7.2 NFT in Clinical Population

Clinical populations related to pathologies characterized by dysfunctional regulation of cortical arousals, such as epilepsy (Sterman & Friar 1973) and attention deficit hyperactivity disorder (ADHD) (Linden et al., 1996; Lubar et al., 1995a; Rossiter & LaVaque, 1995; Shouse & Lubar, 1979) are targeted for almost 50 decades now. As an alternative to pharmaceutical medications, which have varying rates of treatment success and the potential for adverse side effects on the nervous system (Rosenberg & Gershon, 2012), exploration of the therapeutic potential of NFT has increased in recent years. Many of the behavioral difficulties being studied are ones that have impacts on learning experiences, including ADHD (e.g., Lubar & Shouse, 1976; Moriyama et al., 2012); Autism Spectrum Disorder (ASD) (e.g., Coben & Padolsky, 2008; Jarusiewicz, 2002); Learning Disabilities (LDs)(e.g., Fernández et al., 2007; Thornton & Carmody, 2005, Orlando & Rivera,2004); anxiety (Hammond, 2005), obsessive-compulsive disorder (Hammond, 2003), and depression (Hammond, 2005). The behavioral difficulties and dysfunction in the mental process are intensively studied, especially in patients with traumatic brain injury (Rajeswaran & Bennett, 2019). The studies provide evidence for the attention and memory function (Rostami et al., 2017) and NFT as an influential contributing factor for normalization of qEEG in TBI patients, which implications clinical decision-making of EEG-NFT as a viable alternative to be offered to TBI patients (Gupta et al. 2020).

1.7.3 NFT intervention in Healthy Population

Doppelmayr and Weber (2011) refer to 'healthy' individuals as "those without measurable cognitive deficits." While some researchers are looking to neurofeedback as a tool for 'normalization,' others explore the performance-enhancing effects of NFT with these healthy populations. The underlying rationale of using neurofeedback training to enhance performance is one based on associations. By identifying associations between particular patterns of cortical activity and specific states or aspects of behavior that are classified as 'optimal,' one can attempt to train an individual to enhance performance by mirroring the pattern of cortical activity seen during such optimal states. It has been suggested that research aimed at enhancing performance has several distinct aims. These include controlling the level of arousal, attention, and motivation, optimizing the level of autonomic control, and the ability to shift states at will, as well as developing rehabilitative interventions for athletes suffering an injury (Landers, 1985; Norris & Currieri, 1999; Wilson & Gunkelman, 2001).

EEG NFT has been used to influence performance within three main areas: including sport, cognitive performance, and artistic performance (Gruzelier, Egner, & Vernon, 2006), and most of the researches falls into two distinct camps of protocols, on the one hand, the slow-wave protocols (the alpha and alpha-theta protocols), and on the other the fast-wave protocols (SMR and beta protocols). Alpha-theta and SMR-beta based protocols continue to dominate the field, remaining the most extensively investigated and applied (Leach, 2014).

As the present proposal focuses on cognitive and affective parameters, Gruzelier (2013) 's recent extensive review is followed for direction, and the significant studies reported for working memory and mood are considered.

In recent years, researchers focused on intervention practices that include reviews on behavioral interventions to increase social interaction (Hughes et al. 2012), social skills training (Camargo et al. 2014; Walton and Ingersoll 2013), peer-mediated interventions (Carter et al. 2010), exercise (Kasner et al. 2012), naturalistic interventions (Pindiprolu 2012), adaptive behavior (Palmen et al. 2012), augmentative and alternative communication (Schlosser and Wendt 2008), and computer- and technology-based interventions (Knight et al. 2013).

Numerous studies in autism; (a part of the autism spectrum, DSM-IV) concluded that this population has mainly problems with behaving in society or lack of social-communicative skills, such as imitation, empathy, action perception (Pelphrey & Carter, 2008; Misra, 2014) and joint attention (King and Lord, 2011). Accordingly, various types of therapies were applied for its treatment, i.e., speech therapy, psychopharmacological treatment, visual schedules, sensory integration, and applied behavior analysis (Green et al., 2006). These therapies aimed to improve social interaction, behavior, and communication (Bassett et al. 2000). However, these studies improved social communication and language skills but showed less promising results (Coben et al. 2010). Further, Coben suggested a biomedical intervention other than these therapies to target the core symptoms and problems associated with autistic spectrum disorder (ASD) intervention by Neurofeedback training. Since social adaptation problems are common in Autism Spectrum Disorder; hence mu rhythm over the sensory-motor cortex was trained and intervene using NFT. There is several evidence in support of this statement.

In some previous researches, researchers examined the effects of NFT training on the mu rhythm (Coben & Hudspeth, 2006; Pineda et al., 2007) and found that operant training of the mu rhythm resulted in EEG changes and improved imitation behavior and attention in children diagnosed with autism spectrum disorder (ASD).

Similar studies indicated significant mu wave suppression in autistic children with otherwise typically developed populations when Neurofeedback intervention (Martineau et al. 2004; Oberman et al. 2005). Coben and Hudspeth (2006) studied fourteen children with ASD who were identified with high Mu rhythm levels (distorted alpha-like) activity. They also showed less or no suppression of mu during observational activity. They were provided assessment guided neurofeedback training sessions to enhance mu power and connectivity. Both groups showed improvements in neurobehavioral and neuropsychological measure levels. There was a significant reduction in mu activity and improved social and emotional functioning in individuals diagnosed with ASD after providing coherence training).

However, mu activity was reduced only in the coherence training treatment group; on the other hand; increased coherence was linked with lesser mu activity and improved social cognition. Coben (2007) planned a controlled neurofeedback study, mainly focused on intervention for social skill deficits based on a facial/emotional processing model. The study was carried out with fifty individuals with autism. All were undergoing neurofeedback training, pre, and post neuropsychological, QEEG, and parent rating scale assessments. Participants were divided into two groups of twenty-five each. One group which received coherence training showed significant improvement in skills and visual perceptual abilities.

Detailed history evidenced that autistic disorder was diagnosed using neurofeedback in 1994, carried out by Cowan and Markham. This study was conducted on an eight-year-old girl with a diagnosis of high functioning autism. Her detailed EEG analysis was recorded during eyes open and resting conditions. Cowan and Markham found abnormal alpha with (8-10Hz) frequency in the parietal lobe and theta with (4–8 Hz) frequency in the occipital lobe when the recording was going on. After fixing a neurofeedback protocol of 21 sessions, they observed a significant suppression in parietal and occipital lobes to suppress the alpha and theta activities. Results showed increased attention, decreased autistic behaviors, and improved socialization based on parent and teacher reports (Cowan and Markham 1994, Coben 2010). Then, neurofeedback was set as a trend for treatment in autism spectrum disorder and various neurodevelopmental disorders.

Accumulating evidence links the QEEG findings of two boys of age eight years old with autism (Sichel et al. 1995; Ibric and Hudspeth 2003) treated the boy with mild autism by enhancing the SMR (12–15 Hz and suppressing theta (4–8 Hz) waves from the sensory-motor strip and parietal lobe. Positive changes were noticed across his symptoms by providing 31 sessions of monopolar neurofeedback training. Another case was treated successfully by Ibric and Hudspeth (2003) using neurofeedback. Followed by forty training sessions for theta suppression and alpha enhancement, results showed positive changes in obsessions, involuntary movements, improvement in sleep, and aggressive behavior.

More specifically, multiple studies presented by Thompson and Thompson (1995, 2003a). Initially, Thompson and Thompson (1995) presented three cases of children with autism and Asperger's disorder whose neurofeedback protocols were primarily SMR enhancement and theta suppression at parietal and temporal scalp locations (P4-T4). Although these cases reported improvements in behavior and socialization skills, but fail to conclude the possible benefits of this technique and encouraged future work. Following continuous data collection with hundreds of patients, they concluded successful treatment outcomes (Thompson and Thompson 2007). Another two group studies of neurofeedback for ASD were carried out by Jarusiewicz 2002. The first study included twelve children; each was assigned to an experimental or a control group. The experimental group received a mean of 36 treatment sessions (range = 20–69). Treatment protocols were based on the Othmer Assessment (1997) to determine over-, under-, and unstable arousal. The outcome was accessed by using Autism Treatment Evaluation Checklist (ATEC; Rimland and Edelson 2000). After completing neurofeedback, training children showed an average 26% reduction in the total ATEC rated autism symptoms while only 3% for the control group. The experimental group showed improvement in socialization, vocalization, anxiety, schoolwork, tantrums, and sleep, while the control group showed less improvement. Parents reported changes but no objective measures utilized.

The second pilot study of the effects of neurofeedback was carried by Kouijzer et al. (2009a). Fourteen children with ASD participated under treatment and control group, with matched age, gender and intelligence. The treatment group received 40 sessions of neurofeedback treatment to inhibit Theta activity (4–7 Hz) and enhance SMR activity (12–15 Hz) at scalp location C4. QEEG analysis, executive functioning tests, and behavior rating scales (CCC-2, Dutch Autism Scale) were recorded as pre and post-analysis. The neurofeedback trained group clearly, indicated significant improvement in attentional control, cognitive flexibility, and goal setting compared to the control group. Findings of parent rating scales also showed improvements in social interaction and communication skills. This research group extended their work and planned a 12-month follow-up of the treated patients with ASD (Kouijzer et al. 2009b). The basis of findings from changes in executive functioning and behavior suggested long-lasting neurofeedback effects for children with autism. All these studies were pilot studies; they had a small sample size. Although they showed positive results, more controlled research with a larger sample size was needed due to the small sample size.

Studies using electroencephalography (EEG) focused on abnormal Mu rhythms. Mu rhythms are electrophysiological biomarkers to show mirror neuron activity in children with autism, and it was assumed that if neurofeedback could lessen these anomalies, it will lead to improvement (Oberman et al., 2005; Bernier et al., 2007; Oberman et al., 2008). Twenty-seven children with high functioning autism were studied by Pineda et al. (2008) in two continuous experiments. In the first experiment, Neurofeedback training for 30 min for mu wave was provided at 8-13Hz, which was inhibited for EMG at 30–60 Hz. Small changes were notices when accessed on Parent rating scale data (Autism Treatment Evaluation Checklist (ATEC); Rimland and Edelson 2000). In the second experiment, 19 children with high functioning ASD participated in the study. Neurofeedback training sessions were similar to the first experiment except for the reward point; now, it was 10-13 Hz. Parent ratings showed a small but significant change in ATEC Total score as there was a reduction in symptoms. Although the small sample size was the primary concern for any sensory or cognitive changes, they showed positive changes in some areas, according to their parents.

1.7.4 NFT Intervention Studies (Indian)

Several behavioral and biological interventions were available, which were explicitly proved beneficial for the level of functioning and quality of life for people with ASD. However, few have been scientifically and systematically investigated (Gupta B., 2015). The findings of the present study advocated that the method and setting of delivery of the intervention could also produce positive changes or outcomes in the areas of language and communication of ASD such as (gestures, conversation skill, echolalia, and stereotypes use words), adaptive behavior and socialization (eye to eye contact, facial expression and body language, joint attention, and quality of group interaction), imitation skill and imaginative play (make-believe play and pretend play), recognition of emotions and improvement in real-life social skills (the child was able to answer questions from the peer, responded to peer play, took the initiative for play, and asked peer for assistance). Among all these applied behavior analysis-related interventions showed positive treatment effects, mainly on IQ in the milder form of ASD. However, there was a need for biologically-based treatments in challenging behavior like self-injury and aggressiveness. However, disorders, i.e., ASD, attention-deficit–hyperactivity disorder (ADHD), depression, and obsessive-compulsive disorder, which share psychiatric co-morbidity, need alternative treatments. Moreover, most of these interventions have been proven to be ineffective (Patel et al., 2010).

Among these presently discussed alternative treatment approaches, neurofeedback has gained increasing attention in recent years as a treatment for children with ASD. Meta-analytical evidence suggested the effectiveness of neurofeedback treatment in comorbid conditions in ASD, i.e., in attention and impulsivity in children with ADHD (Singh et al., 2015). According to these studies, it has been proved that neurofeedback is effective for ASD core symptoms. Co-morbidity of symptoms of ADHD in ASD (Manohar et al. 2018, Gnanavel et al. 2019) shows no apparent differences among these. As a confusing state in the current classification system, it is pretty difficult to diagnose ADHD and ASD, which also shows less research on this issue in the past. Novel neuroimaging techniques, i.e., QEEG including diffusion tensor imaging (DTI), have been utilised to demonstrate neurobiological changes that correspond with clinical severity in neurodevelopmental disorders. This might be a future tool to assess the additive severity of comorbid conditions in this regard (Razek A, 2014).

1.7.5 Mu Suppression to improve Social Cognition with Typical and Atypical Population

Mu suppression is recognized in two conditions i) when one does some motor activity or visualizes performing a motor activity (Gastaut 1952, Pineda 2005), ii) when one observes another person performing a motor activity or an abstract motion with biological characteristics (Muthukumaraswamy et al. 2004, Oberman et al. 2007). These conditions showed the mirror neuron system's involvement in mu wave suppression (Oberman et al. 2007, Pineda et al. 2005). From infancy, Mu waves play a significant role in imitation. It has been proved that this ability to imitate plays a vital role in the development of motor skills, cognition abilities, and understanding causal information through social interaction (Nyström et al. 2011, Marshall et al. 2011, and Berchicci et al. 2011).

A study by Bernier and his colleagues, 2014, reported that Mu rhythm exists in both typical and atypical developed populations (Bernier et al. 2014). They examined and found a significant relationship among social cognitive functions and Mirror Neurons in both group's individuals. According to researchers such as Jaime A. Pineda and his colleagues, 2011, EEG Mu suppression in a normal population is directly related to information process in social situations, the theory of mind, and empathy, and suggested a connection between mu suppression and social adaptation (Singh, F., Pineda, 2011).

If we emphasize atypical developed populations, i.e., ASD, we found a group of researchers believed that excess of mu waves is present in Autism Spectrum specifically, which affects various motor functions, attention, and various cognitive processes (Ramachandran and Oberman 2006, King and Lord, 2011). These deficits may be associated with dysfunction of the mirror neuron system (MNS) (Williams et al., 2001; Burns, 2006).

1.7.6 NFT Intervention on social cognition in Autism

Previous studies in autism; (a part of the autism spectrum, DSM-IV) concluded that this population has mainly problems with behaving in society or lack of social-communicative skills, such as imitation, empathy, and joint attention (King and Lord, 2011). Accordingly, various types of therapies were applied for its treatment, i.e., speech therapy, psychopharmacological treatment, visual schedules, sensory integration, and applied behavior analysis (Green et al., 2006). These therapies aimed to improve social interaction, behavior, and communication (Bassett et al. 2000). However, these studies improved social communication and language skills but showed less promising results (Coben et al. 2010).

Further, Coben suggested a biomedical intervention other than these therapies to target the core symptoms and problems associated with autistic spectrum disorder (ASD) intervention by Neurofeedback training. Since social adaptation problems are common in Autism Spectrum Disorder; hence mu rhythm over the sensory-motor cortex was trained and intervened using NFT. There is several evidence in support of this statement. In some previous researches, researchers examined the effects of NFT training on the mu rhythm (Coben & Hudspeth, 2006; Pineda et al., 2007) and found that operant training of the mu rhythm resulted in EEG changes and improved imitation behavior and attention in children diagnosed with autism spectrum disorder (ASD). Coben and Hudspeth (2006) mentioned a significant reduction in mu activity and improved social and emotional functioning in individuals diagnosed with ASD after providing coherence training. Similar studies indicated significant mu wave suppression in autistic children with otherwise typically developed populations when intervene with Neurofeedback (Martineau et al. 2004, Oberman et al. 2005).

1.8 SOCIAL COGNITION IN INDIAN POPULATION

We are always surrounded by a world full of humans in our daily routine called society or social environment. To fit in this world, we need to understand how others feel, perceiving, behaving, how to respond in social situations and how to take the perspective of others. This is like feeling part of society to feel inclusive to enjoy life, be happy, and adapt to the social environment. It starts at the very early stage of life after birth. However, a large population shows impairment in public health analysis, such people categorized into social cognitive deficits. This is even more significant for a country like India. India is one of the most diverse nations globally based on language, religion, and culture. Therefore, understanding diversity on top of requirements for social cognition to adapt.

1.8.1 Rationale

Considering the nature of findings (conflicting results, similar results with different protocols, the unclear underlying mechanism of effect), the nature of social cognition improvement at a theoretical level is required. In contrast, there are numerous issues to be clarified at a methodological level, such as training schedules, sessions length, frequency, electrode placements, reward and inhibit bands.

To date, much remains to be developed in terms of validating findings in this body of research. While Baydala and Wikman called for "randomized, double-blind, placebo-controlled trials" as far back as 2001, this degree of rigor in the field has only recently been attempted in a pilot study investigating neurofeedback and ADHD performed by Arnold et al. (2013). Noting the partial controls employed in previous studies, Arnold et al. (2013) emphasized reported results' uncertainty. These authors reiterated the need to implement controls in order to cultivate confidence in results thoroughly. Arnold et al. (2013) also sought to address questions about optimal frequency and number of NFT sessions. Regarding the frequency of sessions, their results suggested little difference in treatment effects between those who received feedback twice a week to those who received feedback three times per week. Data also suggest that a total of 30 treatment sessions are adequate in order to observe stabilized effects.

Considering conflicting results and methodological issues in most of the previous studies, the present research proposal aims. The trainability of brain waves on the criteria given by Zoefel, Huster, and Herrmann (2011) for the validation of a neurofeedback parameter: There should be spectral effects within the trained frequency band caused by the training (trainability). These spectral changes should not affect other frequency bands (independence). Finally, it is reasonable to choose a frequency band associated with certain functions to increase the probability of reliable behavioral effects and applicability (interpretability).

1.9 AIM

The present work aims to assess the feasibility of addressing the social cognitive deficit by mu suppression through EEG biofeedback.

1.9.1 Objectives

The present study is based on three premises; Firstly, social impairment is a continuum with ASD at one extreme and TD individuals at another; Secondly, Mu wave reflects MNS activity in theory of mind task, emotional processes and social cognition, in general, and Thirdly, EEG biofeedback could be used to modulate mu suppression for enhancing social cognition.

Hence, the present study aims to explore:

Objective 1: Expression of social cognition dysfunction in clinical and non-clinical and subclinical populations.

Research Gap: The concept of broader autism phenotype (BAP, Folstein& Rutter, 1977) suggests that autism-like symptom exists on a continuum stretching from typically developed normal population to deficient diverse clinical population. Studies report that close family members of children with ASD show autism trait, similarly, individuals in STEM academic areas shows subclinical autism-like symptoms (Moore 2006; Morton 2001; Safer 2012). Although the means between clinical and subclinical samples differ, there is substantial overlap in the two distributions' tails. The BAP should not be used as a proxy for an ASD diagnosis as there are aspects of ASD that are qualitatively unique and not measured by the BAP (Landry, O., & Chouinard, P. A., 2016). Therefore, the present work aims to fill this research gap by exploring social cognition deficit in the clinical, subclinical, and healthy population.

Objective 2: Neurofeedback Training effect on increasing EEG Mu wave suppressing to enhance social cognition.

Research Gap: There are plenty of studies regarding EEG biofeedback in different conditions like epilepsy, ADHD, Schizophrenia, etcetera (e.g., Weiskopf, 2004b, 2007, 2012; deCharms, 2007, 2008; Caria et al. 2012, Sulzer et al., 2013a; Sitaram et al., 2011, 2017; Thibault et al., 2016, 2018). The most commonly used protocols are alpha-theta or theta-beta waves. Few studies (Coben & Hudspeth, 2006; Pineda et al., 2007) target the Mu wave to improve social cognition, including the autistic population only (Kumari M & Sharma A, 2020). To the best of our knowledge, no studies are conducted for mu suppression for enhancing social cognition in the whole population continuum.

Objective 3: Association of Mu rhythm suppression with the theory of mind, emotional processing, and social cognition processes.

Research Gap: MNS-mu hypothesis suggests that it is a neural substrate of all social cognitive behavior related to observation and imitation that allows understanding others' goals and actions (Williams, 2008; Dinstein, 2008). However, the literature is not conclusive about this connection yet. For example, Frith (2003) reported that structural damage to MNS regions of individuals with ASD causes delayed imitation. However, Hamilton (2008) commented that MNS does not support the normal function of an autistic related to imitation tasks, and autism symptoms are recorded due to damage in circuits outside the MNS also. Therefore, the present study will examine the association between mu rhythm suppression and social-cognitive processes as indirect evidence for MNS-Mu Hypothesis.