2 LITERATURE REVIEW

2.1 RESPONSE ABILITIES

We come across many situations in our everyday lives which require us to perceive and respond to a stimulus in a specific manner. Our ability to respond promptly and accurately to such situational demands forms an important aspect of our everyday living. Our response is influenced by several factors like the type of stimulus, ability to perceive the stimuli and ability to execute the response in the form of a motor task. The stimuli can be in the form of visual, auditory or tactile stimulus; which when perceived goes through our reflex arc and delivers the desired response. The visual stimulus, when sensed by the eyes is carried forward to the occipital cortex where the stimulus is perceived, then to the pre-frontal cortex where the decision regarding the movement is made, from where the stimulus travels to the motor cortex where an appropriate response is generated. The response thus generated varies depending on the time taken to respond i.e. response time and the force with which the response is produced i.e. response force.

2.1.1 Response time

Response time (RT) is the time taken by an individual to respond to a given stimulus and is essentially the time duration between the perception of a stimulus and generation of a response.

The RT is inclusive of the time required to perceive the stimulus, to interpret the stimulus, to analyze and plan an appropriate response and the motor execution of the response. The ability to inhibit a response is best before the motor execution
phase. Most studies consider reaction time as the time from stimulus to the performance of the movement, not just the time to initiate the response. According to the operational definition of the present research, we have included these studies under the broader term of RT. Therefore, the terms reaction time and response time will be used synonymously as RT. RT is essential for our everyday functions as it enables an individual to perform an activity quickly and effectively.

Response time depends on a number of factors like age, gender, stimulus duration, stimulus intensity, practice of the task to be performed and whether the task is to be performed within time constraints. An increase in RT affects performance of skilled activities, dynamic balance and agility. A number of factors affect Mean RT in children aged 9 to 16 years to light stimulus when warned was 180.3 and when unwarned was 226.0 msec.

2.1.2 Response force

The force with which an individual responds to stimulus is known as response force (RF). The force with which people respond to stimuli can provide important information about their cognitive and affective processes.

RF is said to be a parameter that determines the intensity of execution of a motor task. The force with which an individual responds depends on a number of factors like the age and gender of a person, stimulus duration, stimulus intensity, stress and whether the task is to be performed within time constraints. The intensity of the stimulus is one factor which is said to influence RF. Sanders et al found that stimulus intensity affected the force production in auditory but not in visual stimulus. Loud auditory stimulus generates arousal whereas visual stimulus does not. According to
Sanders general model of stress, higher levels of arousal can increase the activation of a response.\textsuperscript{63} Hence, higher intensity of auditory stimuli are arousing, while those of visual stimuli are not. Besides the type of stimulus, response force varies with the environmental constraints. For example, lifting an empty glass and a glass full of water requires different amounts of force. This action encompasses our ability to judge the desired force followed by our ability to modulate the desired force. Sufficient motor control is also required to respond promptly in order to modulate the response with appropriate force. Therefore, altered neurological functions will have an influence on the ability to respond and modulate force appropriately.

2.1.3 Response time and response force

Both RT and RF differ in their underlying mechanism but are essential for the smooth execution of a task. Performing a task with time pressure increased RF and reduce RTs among healthy adults, implying that RT and RF are controlled by different mechanisms and are found to be dissociated.\textsuperscript{61} RT is considered as the simplest tool for assessing cognitive function and has been used for understanding an individual’s cognitive motor ability,\textsuperscript{42} whereas RF has been used for understanding the mechanisms for generating motor responses.\textsuperscript{43–45} Inhibitory effects on motor processes can be measured by RF.\textsuperscript{64} Evidence suggests that force produced can be controlled to suit the external situation.\textsuperscript{60} When the kinetic parameters while responding to a stimuli change, it leads to change in the RT.\textsuperscript{60} When different stimuli are provided, a change in force produced to meet the stimuli can cause a resultant change in RT data.\textsuperscript{60}
2.2 **EXECUTIVE FUNCTIONS**

Executive functions (EF) of an individual is said to be a coordinated interaction of multiple neural systems to achieve the desired goal in a flexible and appropriate manner.\(^1\) The prefrontal cortex, controls and integrates information from multiple systems within cortical and subcortical areas, and thereby plays an important role in EF.\(^1\) EF’s are skills which are essential for an individuals’ development (cognitive, social or psychological), success in school and overall mental and physical health.\(^65\) Executive functions is a broad set up processes which include planning, reasoning, inhibition of a pre-potent response and the ability to retain information and then to make a response based on that internal representation.\(^66\) Inhibitory control, cognitive flexibility, and working memory form three core EF’s.\(^40\)

The EF abilities of an individual play an important role as to how a task is performed. The other aspect important in generating a response is the ability to inhibit certain stimuli which aren’t relevant and respond only to those that are relevant for the task at hand. This distinction as to when and how to respond is crucial for one’s survival. Inhibitory control, one of the core components of EF, enables one to selectively attend to certain task, choose when and how to respond and focus on what we choose while simultaneously suppressing attention to other stimuli.\(^40\) Inhibition is an important aspect required both for motor control and cognitive control. Control of a response or inhibition can mostly be exerted between the stimulus perception and response generation or motor execution. The motor response of a stimulus would be the last point where the inhibition would be exerted.\(^67\) EF is impaired in a number of individuals especially those with intellectual developmental disorders.
2.3 **INTELLECTUAL DEVELOPMENTAL DISORDERS**

2.3.1 **Evolution of term**

Intellectual Disability (ID) is the most widely used term for individuals with intellectual impairment. The term Intellectual Disability replaced the term mental retardation which was used in a number of previously published literature including the ICD-10 (WHO 1992) and the DSM-IV (APA 1994, 2000). More recently the ICD-11 replaced the term Intellectual Disability with Intellectual Developmental Disorders which is defined as “a group of developmental conditions characterized by significant impairment in cognitive functions, which are associated with limitations of learning adaptive behavior and skills.” Herein the working group has considered IDD as a meta-syndromic health condition. The spectrum of disabilities under IDD encompasses a number of conditions including Down Syndrome (DS). Several studies still continue to use the term intellectual disability. In order to maintain consistency in the text, we have quoted all these studies synonymously as IDD.

2.3.2 **Epidemiology**

Based on a meta-analysis the prevalence of IDD was found to be more in low and middle-income countries. Prevalence of IDD in developed countries is 10.37/1000 population and that in India ranges from 1/1000 to 32/1000 population. In India, the neonatal causes predominate among the other causes for IDD.

2.3.3 **General deficits in IDD**

Individuals with IDD have an intelligence quotient of 70 or below, and deficits in at least two behaviors related to adaptive functioning diagnosed by 18 years of age.
Adaptive behavior is the performance of daily activities pertaining to social and personal functioning that is expected for one’s age, culture and community environment.\textsuperscript{3,72} Apart from having difficulties in adaptive behavior, persons with IDD have limitations in relevant social, conceptual and practical skills.\textsuperscript{3}

Ability to perform motor skills are impaired among those with IDD. When compared to age-matched control without IDD, individuals with IDD demonstrate poor ability for bilateral transfer of motor skills and were more prone to interference while performing dual-tasks, both of which were attributed to poor bilateral integration commonly seen in IDD.\textsuperscript{73}

Physical inactivity is said to cause premature aging in adults with IDD, especially among those with DS.\textsuperscript{74} Adolescents with IDD were found to have lower endurance, static balance and manual dexterity abilities when compared to nondisabled peers.\textsuperscript{75} Compared to healthy children those with IDD have reduced lung function.\textsuperscript{76}

2.4 DOWN SYNDROME

2.4.1 Evolution of term

Down Syndrome (DS) was first described in 1866 by Dr. John Langdon Down. His ethnic classification of the inhabitants of an asylum in London led to some inhabitants being classified as mongoloid group, and that is how they got the name “mongoloids”; which in due course led to being termed as Down’s syndrome and later as Down Syndrome.\textsuperscript{77} Down Syndrome is the commonest identified chromosomal cause of Intellectual Disability. The intellectual disability is said to be a result of the abnormal development of the CNS, leading to IQ of varying severity.\textsuperscript{78}
2.4.2 Epidemiology

DS is the leading genetic cause of intellectual disability\textsuperscript{79} with a prevalence of 11.2 per 10000 live births in Europe\textsuperscript{80} and prevalence of 6.6 in England and Wales,\textsuperscript{81} 7.7 in the Netherlands,\textsuperscript{82} 8.27 in the US\textsuperscript{83} per 10000 individuals. In India, the urban centers showed a prevalence of 8.7 per 10000 births\textsuperscript{84} and a tribal village showed a prevalence of 14.5 per 10000 individuals.\textsuperscript{85} Individuals with DS are 68.8 times more likely to have ID, 9.4 times more likely to have heart disease, more likely to be diagnosed with ASD, at risk for a number of comorbid conditions and have a higher rate of significant healthcare burden as compared to other children with special health care needs.\textsuperscript{86}

2.4.3 General deficits

Trisomy of chromosome 21 leads to DS, which results in physical, cognitive and structural impairment, the nature of which varies among individuals.\textsuperscript{18,19} They have dysmorphic features, specific physical and neuroanatomical findings, varying levels of cognitive dysfunctions, hypotonia, poor postural motor, fine motor and gross motor abilities to name a few.\textsuperscript{18,19} Perceptual motor competencies of children with DS is more affected than those who are typically developing. The pattern of development of motor skills in children with DS is known to be different or rather atypical as compared to normally or typically developing children.\textsuperscript{15,19}

Children with DS are found to be slower in acquiring new skills and have greater difficulty in demonstrating an acquired skill at a later point in time.\textsuperscript{87} They perform poorly in most areas of motor function, displaying poor motor coordination, motor control and poor fine and gross motor skills.\textsuperscript{12,13,15,20,55,88,89} Dynamic motor dysfunction
is widespread among individuals with DS. It includes balance and postural deficits, co-contraction of agonist and antagonist muscle pairs and longer motion and reaction time.\textsuperscript{90,91} Individuals with DS show interindividual variability in their cognitive and motor impairment.\textsuperscript{92,93}

2.5 EF DEFICITS IN IDD AND DS

Children with IDD perform lower than age-matched controls in most verbal and non-verbal EF tests, especially for inhibition and planning.\textsuperscript{94} When compared to age-matched controls individuals with IDD perform with significantly lower scores when performing EF tasks.\textsuperscript{95} Children with IDD were found to have poor object control skills and EF abilities.\textsuperscript{4} Impaired EF and poor object control skills increase the time needed to perform complex EF tasks.\textsuperscript{4} The deficiency in mental abilities among individuals with IDD may lead to an impaired ability for action planning, decision making and execution of a task with regard to selecting an appropriate response while performing a task.\textsuperscript{19} Most developmental disabilities are characterized with IDD, however inspite of comparable IQ the difference in the cognitive profile of DS is what facilitates further research in this area.\textsuperscript{9} Impaired cognitive functions are seen in DS,\textsuperscript{7} varies from one DS person to another and improves as the age advances.\textsuperscript{96}

Cognitive functions are said to be impaired among individuals with DS.\textsuperscript{7} The level of impaired cognition varies from one DS person to another and is said to improve as the age advances.\textsuperscript{96} The impairments seen in children with DS are commonly attributed to physical dysfunction rather than cognitive and motor control deficits. Explicit memory abilities are lower in children with DS when compared to age-matched typically developing children.\textsuperscript{97} The mental deficiency among individuals
with IDD may lead to an impaired ability for action planning, decision making and execution of a task with regard to selecting an appropriate response to the task.\textsuperscript{19}

Children with DS perform poorly in working memory tasks as compared to TDC and this performance is task specific and cannot be generalized to all WM tasks.\textsuperscript{98} They have difficulty to suppress prepotent information and less able to suppress non-pertinent information. The inhibitory mechanism is general and not specific to a particular function of inhibition. General lack of ability to control irrelevant or no longer relevant information is seen in DS.\textsuperscript{71} Working memory is said to be impaired in children with IDD with an increase in deficit with the level of IDD.\textsuperscript{99}

2.6 **NEUROANATOMICAL ANOMALIES**

Several anomalies in the neuroanatomical structures have been observed in individuals with IDD. Abnormalities in white matter, reduced grey matter volume and significant reductions in cortical thickness, have been implicated as the anatomical cause for reduced functioning and deficits in adaptive behavior seen among those with IDD. Reduced cortical thickness in areas concerned with working memory, have been considered as the primary cause for working memory impairments among these individuals.\textsuperscript{100–102}

Reduced volume in temporal lobe and frontal lobe, coupled with functional and microstructural disturbances in hippocampus, contribute to the cognitive impairments in individuals with DS.\textsuperscript{6,103} When compared with healthy age matched individuals, those with DS were found to have significantly smaller hippocampal volumes and corpus callosum areas, particularly anterior and posterior, inspite of
controlling for small intracranial volume and age.\textsuperscript{104} The patterns of activation of the brain during performance of cognitive measures among individuals with DS when compared to typically developing individuals using a functional MRI study revealed that the neural circuitry in those with DS is atypical in nature showing less active neural networks.\textsuperscript{105}

\section*{2.7 Interaction between Motor Deficits and EF Functions}

Processing information appropriately is essential for producing meaningful goal-directed responses. Cognition plays a crucial role in appropriate processing and execution of a response and thereby aids in motor control. Cognitive and motor functions are found to be related both at the neuroanatomical and behavioral levels. Hence experiences in either cognitive or motor domain, promotes behavioral improvements across both domains, along with development of brain structures mediating these functions.\textsuperscript{106}

Children with IDD are impaired both in motor skills and higher-order EF.\textsuperscript{107} Poor motor functions in individuals with IDD is said to be related to their impaired intellectual functioning.\textsuperscript{4} There exists a high level of correlation between motor ability and executive functions of individuals.\textsuperscript{4,39} Motor performance influences cognitive functions and the vice versa is true as well.\textsuperscript{4}

Motor performance and EF in school-aged children with DS has shown a positive correlation with medium to high effect sizes. Therefore, weaker performance in motor task is associated with poor performance in EF tasks.\textsuperscript{107} The reasons for the same are attributed to the neuroanatomical findings along with abnormal sensorimotor integration among individuals with DS as compared to TDC.\textsuperscript{107}
The perceptual-motor deficits in children with DS could be the reason why they perform poorly in most aspects of fine and gross motor control. Children with DS had impaired ability in the timing and the accuracy aspect of a manual dexterity task. The impairments observed could be attributed to the neuroanatomical abnormalities, in terms of the incomplete development of cerebellum and brainstem, along with poor visuomotor integration. The poor perceptual motor control is also due to the impaired perceptual-motor coupling seen among individuals with DS. They are less accurate than their typically developing peers to discriminate between an inanimate object and a person moving. Their ability to perceive and interpret complex motions is impaired.

### 2.8 Response Time and Response Force Deficits among IDD

Response selection and response inhibitions are two important aspects of cognitive control. The link between intelligence and RT has shown that altered attention and working memory delays the RT. Slower RT has been reported among adolescents with mental retardation, autism and DS when compared to age-matched college going students; with the DS group having the slowest RT. The RT of children with ID who do not get trained in sport specific skills are lesser than those who get trained; who in turn have poorer RT than healthy children not playing sports. Among adolescents with IDD, the speed of information processing increases with age irrespective of their level of intellectual disability. This speed of development of information processing is slower than typically developing peers.

The timing required to perform activities is impaired, which could be responsible for the slowness of movements seen in DS. Increased variability in performing
activities, reduced accuracy and altered ability to produce the desired force for performing activities is seen in individuals with DS.\textsuperscript{55} The ability to predict the time required for performing movements is impaired in children with DS.\textsuperscript{20} The deficit in the timing aspect of motor control could be responsible for the slowness of movement seen in DS.\textsuperscript{20} Individuals with DS demonstrate highest variability in manual dexterity tasks that require accuracy and timing in bimanual coordination.\textsuperscript{15} Finger coordination, ability to control both individualistic and synergistic movements is worse in DS compared to persons without DS. Increased variability in performing activities, reduced accuracy and altered ability to produce the desired force for performing activities is seen in individuals with DS.\textsuperscript{55} They have deficits in bimanual skills, visuomotor skills and skills which require faster movements.\textsuperscript{15}

DS persons are slower in performing a movement and in performing tasks which require force production. Movement strategies used by DS exhibit different patterns of activation while performing a movement.\textsuperscript{111} The co-contraction strategy of muscle activation used in DS, is adaptive in nature favouring safety rather than efficiency.\textsuperscript{91} The lack of efficiency in movements could be a reason for their clumsy appearance.

Although most children with DS perform daily tasks as well as TDC, there are some variations in the way they perform tasks. Although functionally able, they appear to perform movements in a ‘clumsy’ manner which reduces their efficiency in performing a task. Widely attributed to their low muscle tone and genetic variance, clumsy movements in DS can be due to postural dysfunction, problems with sensory motor integration, motor coordination, etc. The clumsy movements are basically an
inability to adjust to the changing demands of the tasks and the environment, i.e., inability to respond appropriately to changing stimulus. Lack of opportunity to learn or practice tasks in right way contributes to the clumsiness.

However, attributing the dysfunctions seen in DS to neuroanatomical and genetic reasons leads to preconceived notions that the impairments in DS cannot be improved with training. The clumsiness or poor coordination seen in DS are not an obvious outcome of their genetic abnormality. Rather it is due to a complex adaptive strategy which has developed over a period of time as a compensation to the altered motor control in DS.

### 2.9 Implications towards RT and RF across task constructs

Our ability to respond modifies with change in task constructs. Dual-task impairments are seen in children with DS as compared to TDC. The ability to dual-task among individuals with DS is significantly lesser as compared to the other groups. Whether the dual-task deficits are present among younger individuals with DS remains to be explored. Ability to modulate force is important for our everyday actions. For example, preventing an object from slipping from our hand and throwing a dart, both these activities required force to be modulated in a different manner. Choice response abilities are crucial for the individuals especially when deciding how to respond when multiple stimuli are presented. Motor ability of an individual is said to be the best predictor of their functional status. There exists a need for exploring dual-task abilities, ability to modulate force and choice response abilities among those with IDD. A better understanding of these abilities will help devise treatment interventions targeted to improve them and thereby influence their life skills.
2.10 INTERVENTIONS AMONG INDIVIDUALS WITH IDD

Individuals with IDD have lesser exposure to enriching environments than their healthy peers. A study performed among adolescents with IDD attending a special school showed that they chose leisure activities which were passive and solitary in nature. There is a great emphasis on exercise among individuals with IDD which lead to both motor and cognitive benefits.

Physical exercise showed a moderate effect size along with improved cardiovascular fitness among individuals with IDD without DS. A large effect size was observed on balance measures indicating that exercise was the best way to prevent falling injuries among those with IDD. In addition, the meta-analysis revealed that high frequency exercises and short duration exercises yielded better results. Eight weeks of aerobic exercise program helped improve lung function among children with IDD. Physical exercises are also said to reduce anxiety levels among adults with IDD.

Children with DS are said to have a huge potential to improve their motor performance. Variability of practice has shown better effects on motor practice than practice of a single task. Similar views have been seen in individuals with IDD. Variability of practice have shown beneficial effects in DS in terms of control of individual finger actions and also multi-finger coordination. There is a need for developing therapies which improve cognitive functions and prevent cognitive decline among individuals with DS and those with IDD as a whole.

Children with DS who underwent early interventions were found to have higher levels of intellectual and adaptive function compared to children with DS who do not undergo early intervention. Hence, the need to evaluate and train the
deficiencies in the components of motor control in children with DS and IDD without DS need attention. Apart from having an influence on motor control, the training can help improve the adaptive functions and thereby the intellectual functions in children with DS. Behavioral interventions have led to gains with large effect sizes in adaptive behavior, IQ, and communication among young children with IDD.\textsuperscript{118}

Interventions among children with DS have predominantly focused on training both gross and fine motor functions. Training programs have aimed at improving balance,\textsuperscript{119,120} strength,\textsuperscript{121–125} fine manual dexterity and grip strength,\textsuperscript{126} motor skills\textsuperscript{127} and motor control outcomes.\textsuperscript{128} There were a wide range of intervention strategies which were used to target these outcomes. The most common ones were jump skill training,\textsuperscript{129,130} aerobic training,\textsuperscript{36,131,132} treadmill training,\textsuperscript{133–136} hippotherapy,\textsuperscript{137} aquatic therapy,\textsuperscript{138,139} resistance training,\textsuperscript{123,140,141–143} virtual reality,\textsuperscript{125} sensorimotor training,\textsuperscript{120,144} and combined exercise training and endurance training.\textsuperscript{145}

Performance of motor skills is known to be related to improvements in EF among DS\textsuperscript{107} and those with IDD.\textsuperscript{4} Interventions that address qualitative motor skills especially object control may lead to beneficial effects in children with IDD.\textsuperscript{4} Object control skills, which involves controlling objects using the hand like catching and throwing, is a part of fundamental movement skills which are essential for the development of complex movement patterns required for participation in sport or physical activity.\textsuperscript{146} Interventions which can address anticipatory abilities of children and their motor sequencing abilities may improve their EF abilities and lead to better motor responses in complex situations.\textsuperscript{4} Motor and executive function abilities seem
Eight weeks of training in adolescents with DS resulted in improvements with manual dexterity which related to improvements in EF.\textsuperscript{147}

Although any kind of physical activity is said to improve cognitive functions in persons with DS, a combination of interventions may result in better outcomes.\textsuperscript{148} Early interventions which facilitate combined training of motor skills and cognitive abilities are required to be focused on.\textsuperscript{107} Training of both cognitive and motor functions has led to the recent trend towards combined cognitive motor training.

A study done by Wuang et al., compared the effect of 24 weeks of training with virtual reality using Wii games against standard occupational therapy interventions indicated that Virtual reality helped improve motor proficiency, sensory integration functions and visual-integrative abilities of children with DS.\textsuperscript{149}

Computerized working memory training among adolescents with mild to moderate IDD showed an improvement in verbal short-term memory but not response inhibition and fluid intelligence after.\textsuperscript{150} Practice and training ranging form of computerized training to aerobic training is said to have an improvement in EF in any age group.\textsuperscript{40} Training which is flexible in nature is said to have a greater influence on executive functions of individuals.\textsuperscript{151}

Video game based training is said to be a form of flexible training program.\textsuperscript{151} Video game training is said to be a promising method for training cognitive abilities as they are said to be more engaging and entertaining than traditional training methods.\textsuperscript{152} Video games which are strategy based, are said to have an influence on the EF abilities of elders.\textsuperscript{151} Video games are predominantly studied using real-time strategy video games and exergames.\textsuperscript{151–153}
The therapeutic effects of video games have long been propagated among children and adolescents.\textsuperscript{154} Video game based training can be considered as part of training regimen to help improve the speed of processing of participants.\textsuperscript{155} Implications for potential benefits from cognitive training using video games have been suggested among individuals with IDD.\textsuperscript{156} However, there are very few studies with less sample size to support video games.\textsuperscript{156} The games designed for IDD need to be simpler, which limits comparison with their peers. Moreover, strategy based games may prove difficult and action based games may prove too violent for individuals with IDD. The immediate and long-term effects of video games on cognitive abilities need to be seen.\textsuperscript{156}

2.11 IMPLICATIONS TOWARDS TRAINING OF RESPONSE ABILITIES AMONG CHILDREN WITH IDD

The increase in RT has said to associated with increasing mortality.\textsuperscript{47} Inspite of the mortality risk, RT research has been focussed on sport specific training and less among those with intellectual disabilities.

Virtual reality, biofeedback, neuromuscular training, plyometrics, and sport specific training all are said to improve RT.\textsuperscript{46,52,157} Training has also shown to improve their RT abilities in individuals with IDD and children with DS.\textsuperscript{39,53,54} Video game based training also helps improve RT.\textsuperscript{40}

A study done by Un et al. evaluated the reaction time of 20 healthy children not participating in sports, 20 trainable mentally retarded children not participating in sports and 20 mentally retarded children playing basketball. It was observed that the mentally retarded children playing sport had better RT compared to those not playing
the sport. Physical activity and sport specific training thereby are implicated towards improving RT among children with mental retardation.\textsuperscript{22} Physical fitness training has shown to improve RT among young adults with mild intellectual disability without DS.\textsuperscript{53} A pilot study performed by the authors revealed that training children with DS with bimanual activities in community-based settings helped improve their RT.\textsuperscript{54} Whether training would improve RT across children with IDD, would be worth exploring. Being components of response dynamics, whether training could be targeted towards improving both RT and RF among children with IDD would help widen our understanding of response abilities among children with IDD.

Training of time and force together, however, has not been explored. A study performed by Alpkaya et al assessed whether acute stretching of soleus and gastrocnemius would alter the RT and force production and found no significant changes in the outcome with passive stretching.\textsuperscript{158}

The practice of tasks improves the accuracy of performance and ability to produce accurate force and to stabilize the total force control in individuals with DS.\textsuperscript{55} Another study showed that DS do not have decreased ability to generate force. Rather with training and practice, they can move faster and generate more force, without losing accuracy.\textsuperscript{51} Hence, practice can bring about an improvement in the force production and force control in performing tasks, along with improvement in accuracy of performing tasks.

Studies suggest that attention towards interventions which are attractive in nature should be considered while training individuals with IDD.\textsuperscript{150} Shifting from the traditional forms of training to develop newer methods of training which are simple
enough to allow training of those directly in contact with individuals with IDD would be a worthy pursuit.

The way motor skills are mastered depends on the opportunities available for mastering these skills. From early in their life, children with DS are known to have difficulties in processing information and manipulating toys, which impairs their ability to explore and learn from their environment. Object control skills are developed predominantly during play and sport activities which requires one to adapt to changing environmental constraints and EF of the individual. Motor problems that inhibit participation, social isolation, trouble with communication are some of the barriers which limit the provisions for learning among those with IDD. Participation in leisure activities and play are very important aspects of an individuals’ growth. Barriers to access or reach the location of leisure facilities are considered as the major hindrance to participation in leisure activities, as reported both by parents and adolescents with IDD. This leads to a need to address alternate modes of intervention among children with IDD. Studies have targeted both home based and school based training among children with disabilities. Working memory of children with ADHD was trained using computer based visuospatial working memory tasks which could be performed at home or in school. Computerized cognitive training performed at home or school helped improve working memory and non-verbal reasoning among adolescents in IDD. These studies highlight the implications towards devising school and home based training among children with IDD and DS.
2.12 SUMMARY OF LITERATURE REVIEW

Children with DS and those with IDD are known to have deficits in both EF and motor skills. These deficits lead to impaired adaptive functions which alters their ability to perform tasks in terms of the time taken i.e., response time (RT), and the force with which the task is performed i.e., response force (RF). Both RT and RF aid in smooth execution of tasks and thereby form important aspects of motor control. RT is found to be slower and more variable among those with IDD, especially DS. There is a variability in the force modulation abilities seen among these individuals. These impairments may be more pronounced when assessed under varying task conditions. The study therefore aimed at understanding the response abilities in terms of RT and RF of individuals with DS and IDD across task conditions in a series of experiments.

Training among individuals with IDD has predominantly focussed on motor based training. There is now a shift of focus from pure motor based training to newer forms of training which target either cognitive and motor functions. Executive function abilities and motor skills are found to be related such that training cognitive functions can lead to improved motor function and vice versa. Among individuals with IDD, training cognitive functions and finer aspects of motor control over gross motor training is gaining emphasis. Training the ability to control and manipulate objects and training with specific video games, may lead to improved response abilities leading to better task performance. Training in home based and school based settings allows sustainability and greater participation among those with IDD.
2.13 RESEARCH GAPS

A PubMed literature search combining keywords relevant to response time, response force and intellectual disability, yielded no results, suggesting the dearth in literature to understand the response dynamics of those with intellectual developmental disorders. Although, important aspects of motor control, response time and response force have not been collectively studied among children with IDD. How the response abilities of these individuals vary when assessed across varying task constructs will enable us to understand their response abilities while performing tasks essential for daily life skills.

Training of response time has been studied among those with IDD. However, training of response time and force collectively would be a novel pursuit. Training of RF has not been pursued so far; whereas RT, has predominantly been trained with exercise based interventions or sport specific training.

Inspite of benefits shown in typically developing children, use of video games as a form of training among IDD has been sparsely studied.\textsuperscript{156} Training skills to help improve ability to control and manipulate objects may help improve the execution of task among those with IDD. These two forms of training may help improve the response abilities in terms of response time and response force among children with IDD. The influence of object control skills training or video game based training in comparison to no training, on RT or RF among individuals with IDD, has not been pursued.