The International Journal of Indian Psychology
ISSN 2348-5396 (Online) | ISSN: 2349-3429 (Print)
Volume 11, Issue 4, October- December, 2023
DIP: 18.01.167.20231104, DOI: 10.25215/1104.167
https://www.ijip.in

The International Journal of INDIAN PSYCHOLOGY

**Research Paper**

# Executive Functioning in Autism Spectrum Disorder

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## ABSTRACT

This paper explores the role of executive functioning in ASD, both from a broad perspective and with reference to specific symptom categories. We look at the various tests used to make these determinations and assess the legitimacy of them. Ultimately, we discuss whether the executive dysfunction observed in autistic individuals is due to a genuine deficit or simply because classic EF tests are not suited to them and hence, they perform worse on them.

***Keywords:*** *Autism Spectrum Disorder*

Executive control includes a complex combination of mental skills that are relevant to proper functioning in our daily lives. It can be defined as the set of cognitive processes that are involved in regulating behavior and attaining a future goal and involves higher-order cognitive processes such as cognitive flexibility, working memory, inhibitory control, adapting to changing environments and other such skills (Welsh & Pennington, 1988). Autism Spectrum Disorder is a neurodevelopmental disorder that is primarily characterized by deficits in social communication, interactions and repeated behavioral patterns (Hill, 2004). ASD phenotypically persists across three main symptomatic clusters - impaired communication, impaired reciprocal social interactions and repetitive and stereotyped behavioral patterns and interests. It has been shown that executive control difficulties are related to ASD in each of these categories (Geurts et al., 2014). Since these symptoms are all within executive control capacities and have been observed in autistic individuals, there seems to be sufficient evidence for the connection between ASD and executive dysfunction. Although there has been a longstanding and well-established link between ASD and executive functioning, the exact role of executive functioning in ASD has not been determined. Most previous studies focus on the role of specific EF domains and their links with ASD instead of seeking a general understanding of the relationship across all domains (Demetriou et al., 2018). Additionally, since Autism exists on a spectrum, there is sufficient inter-patient variability due to which symptoms and subsequently the effects of EF are not uniform across autistic individuals (Czermainski et al., 2015).

## REVIEW OF LITERATURE

A 2018 meta-analysis of executive functioning with reference to autism spectrum disorder aimed to understand the role of EF in ASD (Demetriou et al., 2018). It also dug deeper into this role with respect to multiple domains within EF and assessed it across various populations and demographics. 235 studies that compared autistic individuals with

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**Received: November 16, 2023; Revision Received: November 25, 2023; Accepted: November 28, 2023**

neurotypical controls on various executive functioning tasks were identified for this purpose. Overall data from more than fourteen thousand participants was analyzed. A random effects model was used, and a subgroup analysis was carried out to test the moderators. There was an above average effect size for executive dysfunction in autistic individuals and effect size remaining more or less stable across domains. However, not all EF measures were found to be clinically sensitive. In fact, there was a lack of evidence for the relationship between individual subdomains of EF and their roles in ASD. Additionally, a limitation of the study was that the method failed to account for individual variability both within each study and across the multiple studies. Since it was a meta-analysis, the data analyzed was priorly combined and hence the individual differences could have been overlooked or their ability to vary the results would've been diminished. Nonetheless, the paper found that there is a definite link between a general executive dysfunction and individuals on the autism spectrum that is universally prevalent.

Executive dysfunction also seems to be prevalent and stable through childhood years in autistic individuals and persists independent of verbal ability and IQ (Robinson et al., 2009). 108 participants were recruited such that half comprised the ASD experimental group while the rest served as neurotypical controls. Multiple measures were used to test a variety of EF sub-skills. Planning ability was measured by the Tower of London task which involved moving beads or disks around a 3-pegboard to achieve a final orientation. The Wisconsin Card Sorting Task required participants to divide cards based on three unspecified rules such as color, number and shape based only on whether they received positive or negative feedback for each decision made and was used to assess mental flexibility. Response inhibition was measured by conducting the Stroop Test and the Junior Hayling Test. The Stroop Test involves ignoring the color word and instead announcing the color of the ink with which the word was written. The Junior Hayling Test had the participants complete 10 sentences correctly and 10 other sentences incorrectly as fast as they could. Verbal fluency was tested by having the participants list as many words as they could for a given category. Results suggested that autistic individuals have significant executive dysfunction as compared to controls. For inhibition and planning, impairments were observed. However, for mental flexibility and fluency no significant impairments were observed, but autistic participants did make more perseverative errors for tasks under these categories. When compared to typically developing controls, autistic participants did not improve with age on tasks for mental flexibility, timed response tasks and lexical capabilities. All these subdomains require a cognitive capacity for inhibiting responses and monitoring oneself. These specific cognitive skills that are predominantly related to executive functioning, seem to be lacking in individuals with ASD. Based on the results of performance on individual tests, it seems like most deficits were in skills that the tests themselves were not primarily testing. For example, while there was no significant difference between the experimental group and control group for the WCST, Stroop task, and Verbal fluency, autistic individuals displayed more preservative errors across. Even for the Junior Hayling Test, performance remained similar between the groups, but autistic individuals struggled on section B and had a harder time coming up with specific strategies to utilize. Follow up work should employ a wider variety of tests that test for these subskills that seem to be harder for the target population rather than focusing on complex domains that require multiple subskills – only some of which are impaired. Yet, it was made clear that whether the deficit lays in subskills or more complex skills, there is a link between ASD and EF, that exists even without intellectual disability. The paper supports the idea that there are multidimensional EF deficits experienced by autistic individuals.

Similar results were found by yet another review article that combined findings from clinical data on 89 children to better understand EF and its connection to ASD. This study looked at executive function as an autistic phenotype with reference to specific autism symptoms (Kenworthy et al., 2009). Each participant was presented with a battery of tests that included measures of socioeconomic status, diagnostic information, general cognitive ability, and four executive functioning tests. The following were the executive function tests used: The BRIEF was used to measure executive functioning in daily life situations and included a questionnaire that had both behavioral regulation and metacognition scales. The TEA-Ch was another battery of assessments used to measure different types of attention with respect to executive function such as auditory attention, divided attention, working memory, inhibition etc. 4 teach subtests were used for this purpose. The Tower of London task was used to check for planning ability and semantic fluency was assessed by having participants name as many words as possible for various categories. A significant correlation between EF and ASD was found for laboratory tasks as well as behavioral ratings. Several regression analyses revealed a correlation between ASD and semantic ability, divided attention, and ability to regulate behavior. This was even though statistical noise from variables like vocabulary and age were accounted for. It is important to note that the EF tests on which the participants did the worst on were not the most strongly correlated to ASD symptoms. The results of the paper were less generalizable as the sample was not culturally diverse. For a clear link to be established between EF and ASD, the deficits must be universal. By recruiting multi-cultural participants, a more universal claim can be made. But, based on the participants sampled, this paper proves that EF relates to ASD in all symptomatic clusters which are impaired communication, impaired reciprocal social interactions and repetitive and stereotyped behavioral patterns and interests.

Not only are EF and ASD connected across symptomatic clusters, but there also seems to be a strong link within specific tasks in each cluster, as proven by multiple research sources. A paper by Joseph & Tager-Flusberg (2004), focused on how Theory of Mind and executive functioning can predict the severity of ASD symptoms. Theory of Mind refers to the understanding that others too have mental states that are external and can be different to one's own. This study explored the link between these two domains and severity of ASD symptoms using a battery of tests that assessed performance on false belief tasks, executive control skills like memory, planning and inhibitory control, and behavioral evaluations of autism symptom severity. It must be noted that the study consisted of only 31 participants, thereby greatly reducing the power of numerous correlations. This also reduces the generalizability of the results and calls into question whether it can be applied to numerous populations. Yet, results showed that neurocognitive deficits in theory of mind and executive function play a causal role in Autism. Both domains explained variance observed beyond what was explained by language level and communication ability alone. Additionally, higher level executive functioning was found to be directly linked to severity of communication deficits that are symptomatic of ASD. Lastly, it was found that Theory of Mind that exists independent of language ability has a more direct link to ASD symptoms.

A common limitation of the previously described papers has been the questions raised about the accuracy of the EF tests in correctly determining whether the impaired performance is due a deficit in EF or can be attributed to the failure of the tests to fairly measure individuals on the spectrum. To answer this, another paper focused on three main executive functions, namely planning, flexibility and inhibition and investigated the testing and/or diagnostic method used to make these determinations (Hill, 2004). A computerized variant of the Tower of London test used to test planning ability. The task was found to be harder for

autistic individuals across the board. However, this difficulty was only apparent for sequences requiring a larger number of moves to execute. Poor performance on this task was also related to non-verbal mental age. Thus, it could be true that while autism plays a role in this sub-par performance, it could also be due to a more general lack of ability. The Wisconsin Card Sorting Task and was used to gauge poor mental flexibility. Two main discrepancies were found with this classic test. Primarily, deficits in the autistic group were only seen in the last stages of task that required an extradimensional shift. Extradimensional shift refers to a transition between two stages wherein the relevant portion of the stimulus in the previous stage becomes irrelevant in the next one and vice versa. Secondly, the task ends based on perseverative errors, which proves to misidentify the deficit. Autistic individuals do not experience a global inability to do well on this task but instead seem to get stuck within the set leading to a perseverative error and consequently a worse score. This study claimed that most on the spectrum do not perform badly on the Stroop Task or other tasks involving inhibition of a prepotent response. However, they found that difficulty arises when these sorts of tasks have a social component or arbitrary rules. Since executive function tests that do not lack rationale do not show reduced performance by autistic individuals, the deficit could be due to an inability to do well without structured rules rather than EF itself. The paper fails to provide alternatives to these tests that should be the focus of future EF work. Furthermore, it only looked at participants from the UK and therefore failed to make a cross-cultural assessment about how test-takers from the East fare on them. Despite these limitations, this study reveals a major loophole in tasks that are frequently used to test for executive dysfunction in autistic individuals and highlights how the tests are not suited for autistic individuals for a myriad of reasons.

The previous studies compiled data from studies involving various lab tasks. The limitations observed raised an important question about whether these lab tasks proved to be a useful measure of executive dysfunction on if, instead, the deficits were due to a third variable all together. Another paper sought to resolve this very question (Kenworthy et al., 2008). To do so, commonly used measures of executive dysfunction in autistic individuals were tested across multiple dimensions. Mainly they were assessed for generalizability, ecological validity and 'real-world' applicability. The foremost finding from this paper was that on classic EF tests such as the Tower task and the Wisconsin Card Sorting Task, when a computer replaces a human examiner, the significance of results that demonstrate a deficit are greatly reduced. So, this shows the difficulty may be tied to a lack of social skills or a discomfort in the presence of humans rather than an inability to do well on what the task itself is assessing. This is contrasted with the idea that both autistic and neurotypical individuals do better on executive-functioning tasks in a laboratory setting than in the real world simply because the laboratory not only provides a quiet, structured environment but numerous cues are also given that help improve performance. The paper also found that new tasks that claim to be more autism-friendly and have more ecological validity such as the BADS or BRIEF, still have many social demands to be successfully completed and hence prove harder for autistic individuals. Furthermore, the study raises the point that neuroimaging techniques such as the fMRI and MRI are also challenging as the participant must be kept still in a confined, noisy space for a long period of time. The paper does concede that new tests that employ virtual-reality seem to be better at reducing the social demands and making EF tests more real-world compatible. Some tests have also been created specially to test EF in autistic individuals and that seems to be the best way going forward. All in all, the paper makes evident that the current tests for EF when used for autistic individuals are thoroughly confounded.

## DISCUSSION AND CONCLUSION

Through this research, it is evident that there exists a definite link between executive dysfunction and autism spectrum disorder. The results from multiple studies, as described above, have shown that these deficits are observed across EF domains. These deficits also seem to persist across the systematic clusters, and many do not seem to improve with age. While many of the studies independently do not cover a universal population, taken together the results are very generalizable and a claim about the universality of this correlation can be made. However, it is important to note that these deficits do not mean that the entire cognitive skill is redundant, and instead only certain sub-skills such as response inhibition, self-monitoring etc. are lacking. Future studies should further analyze these subcomponents within these symptomatic clusters to gain a better understanding of exactly what the deficit is in. This can help make interventions more targeted and therefore more efficient.

Furthermore, an important problem raised was that most classic tests of executive function seem to not work as well for people on the spectrum. Thus, while their performance is already worse than neurotypical counterparts on these tests, it seems to be worse than it is as these tests aren't suited to them. Additionally, many of these tests test a general, broad cognitive domain. However, as explained above, the deficits are more specific. Therefore, these classic tests also fail to pinpoint the deficits in these sub-domains. There is also a large social element involved that makes it even harder for autistic individuals. Since most of the research on this topic today is based on these classic tests and requires human administration, we do not have a thorough understanding of the extent of this dysfunction yet. To add onto this list of problems with EF testing for autistic individuals, most of them do not have any real-world applicability. If we do not know how these deficits manifest in the real world, we cannot create interventions that target them and are applicable to daily life situations. Also, questions can be raised about the culture fairness of these tests. Taken together these problems confound these studies and greatly reduce the validity of these tests.

Since autistic individuals do seem to do better on computerized versions of these tasks, going forth research should try and remove the human component thereby making it easier for autistic participants. This would also have the dual benefit of revealing a more accurate and specific understanding of the dysfunction. Future research should also focus on creating tests that are either culture fair or create different tests for participants from different cultures. This way generalizability of results can be increased, and interventions can be created that help a more diverse set of people. Virtual reality tasks can be used to simulate real world environments and remove the human component from testing. This way the tests are suitable for individuals on the spectrum but have immense real-world applicability.

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***Acknowledgment***

The author(s) appreciates all those who participated in the study and helped to facilitate the research process.

***Conflict of Interest***

The author(s) declared no conflict of interest.

***How to cite this article:*** Maheshwari, D. (2023). Executive Functioning in Autism Spectrum Disorder. *International Journal of Indian Psychology*, *11(4)*, 1798-1803. DIP:18.01.167.2023 1104, DOI:10.25215/1104.167