Exploring trends in cognitive abilities between 2007 – 2015 in India's adult population – Evidence of the Flynn Effect

Theoretical Framework

Improvements in cognitive abilities have been widely observed throughout the 20th century. Within the field of intelligence research, this phenomenon, known as the Flynn Effect, is evidenced through significant increase in Intelligence Quotient (IQ) scores across high income countries (Flynn, 1987; Williams, 2013). Hypotheses have proposed that this positive trajectory may be a result of developmental improvements in factors such as nutrition and the quantity and quality of education (e.g. Baker et al., 2015), amongst others. Recent evidence also shows similar increases in a select few low and middle income countries (Pietschnig & Voracek, 2015), where data is available. While IQ tests are the most comprehensive measure to capture a wide range of cognitive abilities, and remain a valuable tool, they come with limitations. To date, nuances in change of IQ across most countries outside of the high-income-country areas are largely left uncaptured due to the lack in availability of nationally, or even regionally representative data that is both reliable and readily accessible. However, given the importance of understanding comprehensive changes in cognitive abilities to overall human development, it is vital to examine populations from said low- and middle-income countries which make up more than 80% of the total world population. As such, for the time being, we must look to other available measures that adequately capture cognitive abilities in low- and middle-income countries.

India, the largest lower-middle income country, holds more than 17% of the world's population. Thus, insight into a nationally representative dataset on cognitive abilities is particularly intriguing. Not to mention, it has become the most populous country in the world, with a young age structure, which still holds a typical pyramid shape with less older people at the top and more younger people, who will remain or will become part of the labor force, at the bottom (KC et al., 2024). In contrast to the many high-income countries that are currently facing issues of an aging population, the human capital of India's large young population will have wide reaching global implications. It should however also be noted, that while not an immediate problem, India will eventually face the challenge of an aging population. Thus, it becomes important to understand the development of cognitive abilities across different ages within the Indian population. In addition to its size, the country's heterogeneity in terms of social structure, geography, socioeconomic conditions, and education levels, among other factors, make understanding the nuances of cognitive development within its population an incredibly valuable and vital addition to the greater literature on the development of cognitive abilities, human capital and overall human development.

The World Health Organization (WHO) Study on global AGEing and adult health (SAGE) is a comprehensive research initiative that includes nationally representative datasets that aim to understand the health and well-being of older adults in China, Ghana, India, Mexico, Russia and South Africa. Its extensive survey collects data on physical and mental health, healthcare access, economic and social factors as well as overall well-being, amongst others. While its target age groups are adults aged 50 and above, it includes adults aged 18 – 49 as controls allowing for insights into age related development of the different variables. The effort has yielded at least three waves of data collection, and data from the first two waves are publicly available at the time of writing. The SAGE dataset allows for the understanding of health needs and challenges of older populations, and helps to identify factors that influence healthy aging.

Relevant to this paper, the survey includes three cognitive abilities measures, namely testing digit span, verbal recall and verbal fluency. The digit span test presents individuals with a sequence of digits and tasks them to immediately recall these. The task can either be a forward digit span test, where individuals must recall the digit sequence in the same order as presented, or a backwards digit span test, where individuals must recall the digit sequence in the reverse order. The test provides insight into the capacity of an individual's short-term memory and working memory by seeing how much information can be temporarily stored and manipulated based on the number digits that are recalled in the correct sequence (Reisberg et al., 1984). Similarly, the verbal recall test presents individuals with a sequence of words and tasks them with recalling these. The task can either be an immediate recall test, where individuals must recall the words immediately after they were presented, or a delayed recall test, where individuals must recall the words presented after a certain period. Here the order that the words are recalled in does not matter. This test delves into short term, working, and potentially long-term memory by evaluating an individual's ability to store and retrieve information (McCabe, 2008). Finally, the verbal fluency test tasks individuals to name as many words as they can within a given constraint. The task can either test phonemic fluency, whether individuals are asked to generate words that begin with a certain letter, or test semantic fluency, where individuals are asked to generate words that belong to a certain category. They are given a certain amount of time to produce these words. The test provides insight into an individual's executive function, often referred to as the brain's air traffic control, allowing an individual to achieve their goals, and memory amongst various other cognitive skills through the process of correct word retrieval (Miller & Wallis, 2009; Benton et al., 1989).

As such this paper looks to explore the changes in cognitive abilities as measured by the SAGE survey between the first wave, taken in 2007 and the second wave, taken in 2015, in India. It will seek to answer the following questions:

1) Is there an increase in cognitive abilities from wave 1 to wave 2 in India?
2) What are the age trends in cognitive abilities across wave 1 and 2 in India?
3) Is there an increase in cognitive abilities across education levels in wave 1 and 2 in India?

<u>Data & Methods</u>

This paper will conduct a secondary data analysis using the WHO SAGE dataset for India (Arokiasamy et al., 2013; Arokiasamy et al., 2020). It was accessed through a request to the research team which provided data from wave 1 and 2. It was explained that the dataset contained new as well as repeated cases in the older population of wave 2, however paired data was not yet available. Hence, this should be kept in mind when interpreting preliminary findings below. Survey data was collected using representative sampling of 24 016 individuals living in India that ranged between ages 18 – 106. As preliminary explanatory variables, the age, wave number and education level were taken from the survey. Age was transformed into age groups of roughly 10 years (18-24, 25-34, …, 75-85, 86+). Wave 1 was data collected between 2007 and wave 2 was data collected between 2014 – 2015. Education levels included never having been to school, less than primary school completed, primary school completed, secondary school completed, high school or equivalent completed, college/pre-university/university completed, and post graduate degree completed. For the outcome variable, results of verbal fluency, verbal recall and digit span were used. To understand the relationship between age, wave, education and cognitive abilities, multiple linear regression modeling was implemented in addition to descriptive statistical analysis in the preliminary analysis below. The statistical software R studio was used for this, which included the use of the regression analysis packages olsrr, lmtest, as well as packages tidyverse, haven, stargazer (Halvak, 2022) and car. Microsoft Excel was also used to create figures.

<u>Preliminary Results</u>

Wave 1 consists of N = 12198 with 7489 females, while wave 2 consists of a slightly lower N = 11818 with 4946 females and 2702 NA cases. The age group structure in both waves show an uneven distribution across the groups, as shown in Figure 1. The oldest age group, that compiles age ranges 86 - 106 is particularly problematic, as despite covering a range of 30 years, it makes up a combined 0.72% of the total sample. Due to this, as well as closer inspection of the erratic results within this group, we do not consider its results as reliable and remove it from the rest of the analysis.

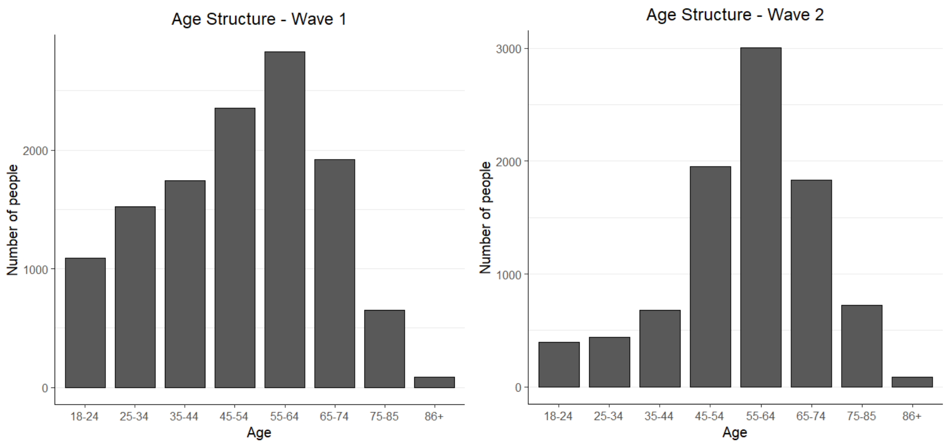

Figure 1. showing the age structure of survey participants in wave 1 and 2

Wave

Examining the mean, standard deviation, and the t test of the cognitive abilities data by wave, as shown in Table 1, one can see a significant increase in performance of cognitive abilities in the second wave across all three measures. As one of the explanations for this result can be due to fact that the number of cases is not evenly distributed across age groups, the variable of age is examined closer.

Table 1 Showing N, mean and standard deviations of digit span scores, verbal recall scores and verbal fluency scores across waves 1 and 2.

Test	Wave 1		Wave 2		*df*	t	*p value*
	Mean	SD	Mean	SD			
Verbal Recall	5.53 words	1.49 words	5.78 words	1.53 words	17756	-11.25	>.001
Digit Span	3.45 digits	1.13 digits	3.50 digits	1.23 digits	17540	-3.11	.002
Verbal Fluency	10.6 words	3.6 words	13.5 words	4.93 words	14592	-42.28	>.001

Age

When adding the age dimension to the descriptive analysis, as shown in Figure 2, the difference between the waves remains. Keeping the issue of presence of repeated cases in older ages in mind, it should be noted that the wave difference is clearly seen across all age groups throughout all three measures of cognitive abilities. Furthermore, there is a higher difference between the younger age groups (18 – 44) across digit span and verbal fluency. Verbal recall shows a similar difference across most age groups, with the exception of age group 35-44 where the difference is smaller, yet still present. In terms of the overall trend across age, there is a negative linear relationship between age and cognitive abilities, where the older the age groups, the lower the scores in all three measures. Verbal recall and digit span both show similar trendlines across their two waves, while wave 1 of the verbal fluency measure shows a flatter trendline compared to the wave 2 samples. Regarding the comparison of age trends across the three measurements, one must keep in mind that these scores are not z-standardized, and thus are difficult to meaningfully compare to one another.

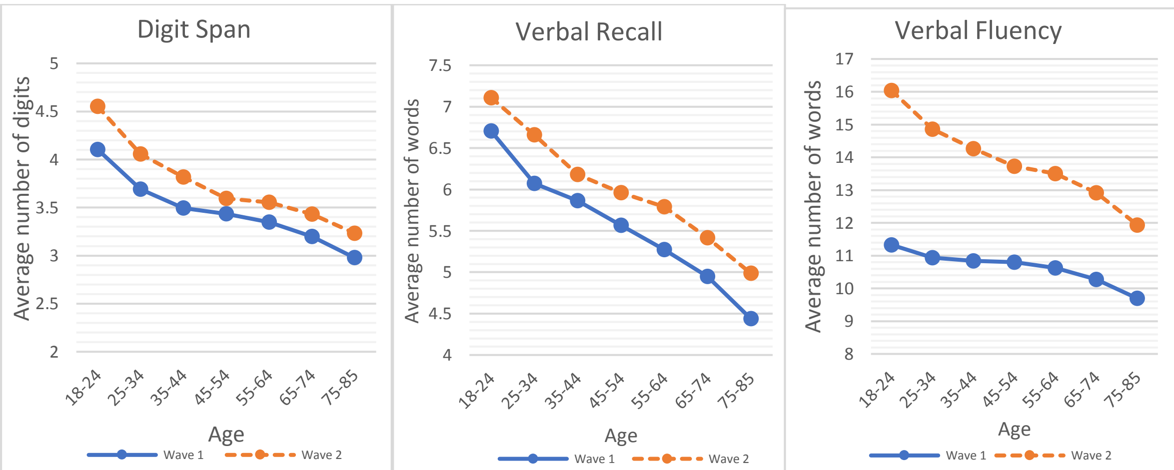

Figure 2. showing average digit span scores, verbal recall scores and verbal fluency scores by age and wave.

Education

When adding the education dimension to the descriptive analysis, as shown in Figures 3, 4 and 5, the relationship between age, wave and cognitive abilities slightly changes. Firstly, when examining the relationship between level of education and cognitive abilities, the trend generally shows a positive relationship, where the higher the level of education, the higher the cognitive score, with the exception of the top two groups. Individuals who have completed an undergraduate level show an average score of 6.84, 4.71 and 14.8, compared to post graduate level scores of 6.78, 4.86 and 14.9 for verbal recall, digit span and verbal fluency, respectively. When looking at it by age, as shown in Figures 3, 4 and 5, post graduate scores can be seen dipping below and above undergraduate scores throughout different age groups. Partial explanations for this can be the low number of cases for post graduate students, which made up 1.5% of the total sample.

Regarding the age dimension, trendlines have flattened compared to previous analyses. A negative relationship between age and cognitive abilities is not always clearly established in all three measurements. The oldest age group scores remain lower than the youngest age group scores, with the exception of wave 2-digit span age group 75-85. Once again this can be due to the low number of cases, making up a fraction of the undergraduate group that make up 4% of the total sample. While all education levels show a clear negative linear trend with age in verbal recall as shown in Figure 5, as well as the no education group with age in digit span scores as shown in Figure 4, this is not the case for verbal fluency as shown in Figure 3. When examining the wave dimension, similar trends as previous analyses can be found in the lower education levels, up until the level of secondary completed, across all three measures. After this, while verbal fluency scores still show a difference in the two waves, as seen in Figure 4, trendlines for wave 1 and 2 cross over at different age groups for high school, undergraduate and post graduate completed groups for digit span and verbal recall.

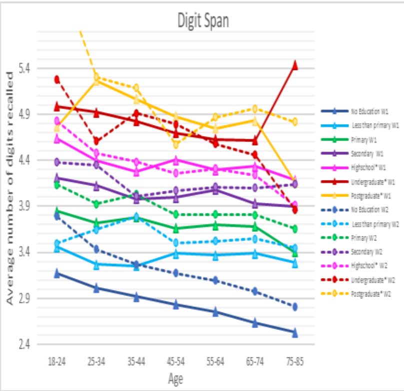

Figure 3 showing average digit span scores by age, wave, and education

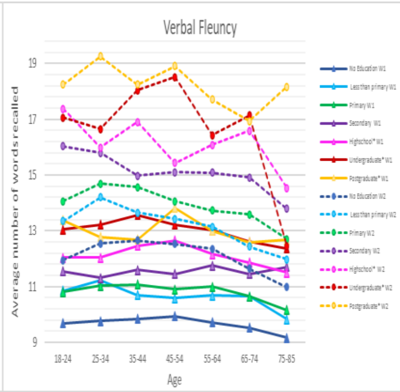

Figure 4 showing average verbal fluency scores by age, wave, and education

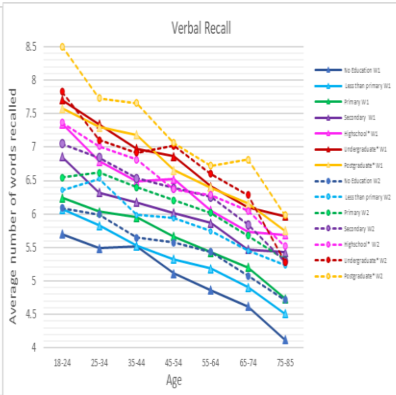

Figure 5 showing average verbal recall scores by age, wave, and education

Regression Analysis (unable to include table due to lack of space)

After checking for assumptions, a multiple linear regression was used to test if age, wave and education significantly predicted digit span scores, verbal recall scores and verbal fluency scores. Three models were created, one for each dependent variable. All independent variables were transformed into dummy variables. Age group 18 – 24 was the base line for the age group variable. Wave 1 was the baseline for the wave variable. No education was the baseline for the education variable. The fitted regression models were as follows:

Model 1: $Digit\ Span = B_0 + Age + Wave + Education + e$
Model 2: $Verbal\ Fluency = B_0 + Age + Wave + Education + e$
Model 3: $Verbal\ Recall = B_0 + Age + Wave + Education + e$

The overall regression for all three models were statistically significant, explaining 32.3%, 20.4% and 26.1% of the variance in digit span scores, verbal fluency scores and verbal recall scores, respectively, as can be seen in Table 2. All predictor variables for models 1, which looked at digit span, and model 3, which looked at verbal recall were significant at a p<.001 level. For model 2, wave and education were significant. However, age groups 25-34, 35-44, and 55-64 were not significant in relation to the youngest age group of the dummy variable, 18 – 24. This is in line with what can be seen in Figure 4.

Preliminary conclusions

Data shows clear evidence of increase in cognitive abilities scores between wave 1 and wave 2. In line with literature, the scores also show clear evidence of decrease in cognitive abilities due to aging. Finally, there is also clear evidence of the impact of education, where, scores improve based on the level of education. These are significant finding highlighting the presence of cognitive abilities differences across time in India, similar to the Flynn Effect observed in higher income countries. Further research in needed in the future where more explanatory factors in addition to education can be added, such as socioeconomic factors, as well as the impact of physical health. Additionally, delving deeper into the historical context of the country and conducting a cohort analysis will provide valuable insights into answering the whys behind these cognitive ability differences.

Next steps for this paper:

- Add the gender dimension in analysis
- Check for interaction in regression model and add additional control variables into regression model
- Look into regional differences and social class & ethnicities differences
- Construct pseudo-cohorts for cohort analysis