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Modern Technology and the Secular Increase in IQ

In 1984 James R. Flynn has published a study showing that the average IQ of Americans has been increasing since at least 1932.[1] He has supported this conclusion with data collected in further 13 countries;[2] now we have good evidence showing that IQ has been rising from Australia through Brazil and Israel to Sweden.

From 2006 it is allowed for students at school exams in New Zealand to use abbreviations that have become customary in SMS texts.[3] Since the primary aim of conventional IQ tests is to predict school achievement, if texting skills become part of the abilities needed for success in schools it could be only a matter of time until text language becomes part of what is measured by IQ tests.[4] Nevertheless, this does not say much about the con-

[1] J. R. Flynn, "The Mean IQ of Americans: Massive Gains", *Psychological Bulletin* 95 (1984), pp. 29–51.

[2] J. R. Flynn, "Massive IQ Gains in 14 Nations: What IQ Tests Really Measure", *Psychological Bulletin* 101 (1987), pp. 171–191.

[3] "New Zealand students may 'text-speak' in exams", http://en.wikinews.org/wiki/New_Zealand_students_able_to_use_txt_language_in_exams. However, some restrictions have been applied by the New Zealand Qualifications Authority: text-like abbreviations cannot be used in tests that require a demonstration of verbal skills, and it is the students' responsibility to ensure that the markers will be able to understand their answers. See "Use of Abbreviations in Exams", http://www.nzqa.govt.nz/news/releases/2006/101106.html.

[4] On the cognitive aspects of text composing, see Valéria Csépe, "Kognitív fejlődés és mobil információs társadalom" [Cognitive Development and the Mobile Information Society], in Kristóf Nyíri (ed.), *Mobil információs társadalom: Tanulmányok* [The Mobile Information Society: Essays], Budapest: MTA Filozófiai Kutatóintézete, 2001; see also Valéria Csépe, "Children in the Mobile Information Society", in Kristóf Nyíri (ed.), *Mobile Communication: Essays on Cognition and Community*, Vienna: Passagen Verlag, 2003, pp. 117–125. On how texting – among others – changes the notion of accepted literacy, see Klára Sándor, "The Fall of Linguistic Aristocratism", in Kristóf Nyíri (ed.), *Mobile Communication*, pp. 71–82. On the educational aspects of mobile phone use see Louise Mifsud, "Learning '2go': Pedagogical Challenges to Mobile Learning Technology in Education"; Attila Krajcsi, "Mobile Learning in Mathematics"; and Marcelo Milrad, "Mobile Learn-

nection between intelligence and technological tools. If bench press becomes a selection criterion in schools, measures of muscular build-up will have great predictive validity in educational settings. But are intellectual abilities more directly affected by tools? Can the increase in IQ scores be attributed to the more and more complex technological environment that surrounds the subsequent generations?

In the present paper I will try to find answers to these questions, or at least evaluate the evidence supporting such a hypothesis. Since many of the readers of this volume are not familiar with the concept and measurement of IQ , I will describe in a nutshell what IQ means and how it is measured. In the next section I briefly discuss the Flynn effect and its possible explanations. A discussion of the role of technology in the explanation of the Flynn effect follows next, and finally a brief section is devoted to how technology changes our conceptions of intelligence.

The Meaning and Measurement of IQ

One of the criterions any psychological test has to satisfy is validity: the constructors of the test have to demonstrate that the test is measuring what it is intended to measure. This condition is usually satisfied by demonstrating that the test correlates with an independent, external criterion of the measured construct. Hence a test that claims to measure intelligence has to correlate with a universally accepted external criterion of intelligence.

The first modern intelligence test was constructed for children by Alfred Binet in 1905. He solved the problem of validity by finding a criterion that is universally acceptable as an external indicator of intelligence: age. No doubt, on average children become more intellectually capable as they grow older.

Binet arranged test items according to the age of the children who are on average able to solve them. The concept of mental age[5] was then introduced: a child has a mental age of 8 if they solve the items that are on average solved by 8 year olds. This could be compared with the chronological age of the child in order to see if the child was ahead or behind in their mental development. Later it was recommended that the proper index should be the ratio of mental and chronological age rather than the difference, as the former is more appropriate in differentiating chil-

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ing: Challenges, Perspectives and Reality", all in Kristóf Nyíri (ed.), *Mobile Learning: Essays on Philosophy, Psychology and Education*, Vienna: Passagen Verlag, 2003, pp. 165–174, 195–208, 151–164, respectively.

[5] Originally "niveau d'intelligence", see R. Fancher, *The Intelligence Man: Makers of the IQ Controversy*, New York: Norton, 1985.

dren with disabilities. Finally it was added that the result should be multiplied by 100 to give results that are easier to deal with. Hence the famous IQ "equation" is: (mental age / chronological age) x 100.

This is, unfortunately, still insufficient for the purpose of measuring individual differences in intelligence in adults. It is nonsense to say that a 60 year old with an IQ of 140 has a mental age of a 84 year old. The intelligence of adults is calculated not by the above equation, but simply by comparing individual scores with the average of the population. Since IQ scores are normally distributed, statistical regularities can be applied to calculate the proportion of people above or below a given value. The average test score of the population is equal to 100 points on the IQ scale, and one standard deviation equals 15 points. Therefore we can calculate that about 2% of the population will be above 130 points, 16% below 85 points and so on (Figure 1).

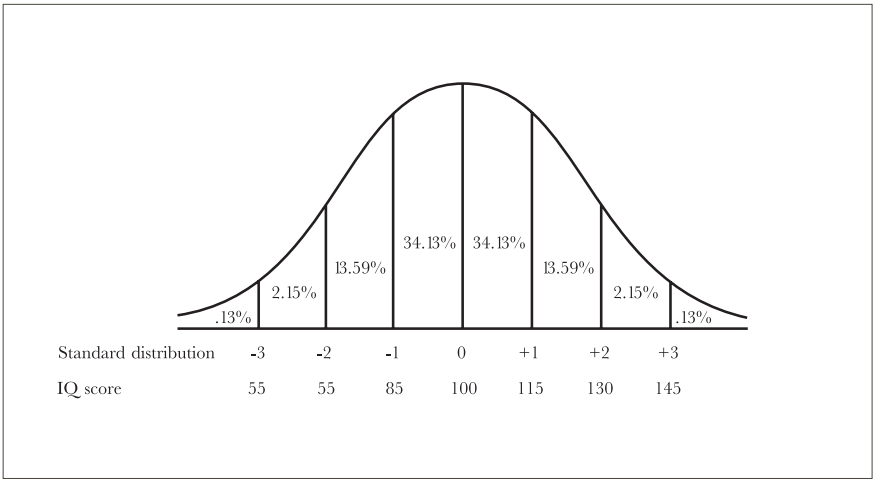

Figure 1
The Gaussian distribution of IQ scores

The most important consequence is that intelligence is not like height. Height is an absolute measure, not a relative one, it does define one's position compared to the average of the population, but to an absolute zero point. Robinson did have a height, but did not have an IQ.

In order to give valid results, all tests have to be restandardized to follow the shifts of the average score of the population, if there is any. Experience shows that there is change indeed, and it is substantial.

The Flynn Effect

Ever since IQ tests were first restandardized, the average score has always been increasing, therefore after every restandardization, better performance on the same test is required for having an IQ of let us say 100. This increase is called the Flynn effect.

The size of the increase varies according to the type of the test. The largest increases have been observed on tests of nonverbal IQ (meaning tests of visuospatial skills, fluid intelligence, and abstract inductive reasoning), whereas gains are smaller on tests of verbal skills or general knowledge, and the smallest gains are on tests directly measuring scholastic aptitude.

The average gains are enormous; the difference between two subsequent generations can be up to a standard deviation in total score (equal to 15 IQ points). According to Flynn, there has been a 21 points increase between 1918 and 1989,[6] with the largest gains recorded between 1972 and 1989.[7]

This means that on an IQ test made in 1930 the average score of the entire population would give an IQ between 120 and 130 according to the original standardization. This means that instead of 2%, 35–50% of the population would have an IQ above 130. And vice versa; if the current standard was applied to people living in 1930, average IQ would be between 70 and 80, and instead of 2%, 35–50% would be diagnosed with mental retardation.

There have been numerous hypotheses proposed to account for the Flynn effect.[8] However, scientific investigation is hindered by the fact that we are here dealing with an essentially historic phenomenon, which cannot be replicated or studied under experimental conditions to see what effect the changing of certain variables has on the magnitude of the Flynn effect. Therefore we have to make a choice between rival hypotheses based on indirect evidence, and by trying to answer such questions as "In which ability domain is the increase most profound?"; "What other temporal change does the Flynn effect correlate with?"; and so on.

The first and foremost question to be answered with regard to the Flynn effect is: are the gains real or spurious? Do the gains in IQ manifested as the increase of average test scores at restandardizations reflect real gains of intelligence, or are they just artefacts showing an increase in IQ without a corresponding increase in intelligence?

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[6] J. R. Flynn, "The Mean IQ of Americans", *loc. cit.*

[7] J. R. Flynn, "Massive IQ Gains in 14 Nations", *loc. cit.*

[8] See U. Neisser (ed.), *The Rising Curve*, Washington, D.C.: American Psychological Association, 1998.

Those favouring the latter explanation argue that the magnitude of the increase is too large to be real. Flynn himself[9] believes so, and argues that IQ tests are not really measuring intelligence. He claims that if between-generation differences are viewed the same way as within-generation differences, then half of our grandparents should be classified as mentally retarted. Another problem is posed by extrapolating the trend to the past: given that the rate of the increase is constant, compared to the present average, the IQs of Newton and Aristotle are approximately -15, and -1000, respectively – given that their IQs were 3 standard deviations above the mean of their time. This, however, is only the case if one also assumes that the increase has been going on for a very long time. Raven[10] points put how absurd it is to extrapolate the increase in height experienced in the 20th century back to ancient times.

Brand[11] also argues that there is no real increase in intelligence; the better performance on IQ tests is due to getting used to and therefore becoming more experienced in taking such tests. This explanation, however, is not very convincing as the magnitude of the Flynn effect is not greater in countries where children regularly come across IQ-type tests as part of their school curriculum (primarily in the US and the UK) than in countries where children take virtually no IQ-type test in school.

Many theorists argue that the Flynn effect reflects a real increase in intelligence. A wide range of explanations have been proposed. One of them emphasizes the role of school education.[12] This is superficially contradicted by the fact that the increase is smallest precisely on measures of knowledge acquired in school and largest on tests that measure abstract fluid reasoning. Nevertheless, the emphasis of school education shifted from rote learning to independent problem-solving in the past decades, which might have resulted in an increase in abstract problem-solving skills, exactly the ones measured by tests of fluid intelligence.[13]

Another explanation claims that the Flynn effect is caused by the decrease of the average number of children in families, and the number of children in a family is negatively correlated with the average IQ of

[9] J. R. Flynn, "Massive IQ Gains in 14 Nations", *loc. cit.*

[10] J. Raven, "Response to Flynn: Searching for Justice: The Discovery of IQ Gains Over Time", http://home.earthlink.net/~rkmck/vault/ravenflyn/ravflyn.pdf.

[11] C. R. Brand, "Bryter Still and Bryter?", *Nature* 328 (1987), p. 110.; C. R. Brand, "A Gross Underestimate of a Massive IQ Rise? A Rejoinder to Flynn", *Irish Journal of Psychology* 11 (1990), pp. 52–56.

[12] E.g. T. Husén and A. Tuijnman, "The Contribution of Formal Schooling to the Increase in Intellectual Capital", *Educational Researcher* 20 (1991), pp. 1–25.

[13] N. J. Mackintosh, *IQ and Human Intelligence*, Oxford: Oxford University Press, 1998.

children in the family.[14] Finally biological explanations have been proposed as well, referring to such factors as improving availability of better nutrition, richer in vitamins and other ingredients having a beneficial effect on development, both *in utero* and in early childhood.[15] This hypothesis does indeed seem plausible. First of all, the similarly large increase in average height, which was parallel to IQ gains in the 20th century, is also primarily explained by the availability of better nutrition. Secondly, also similarly to the increase in height, the Flynn effect seems to have stopped or slowed down, although this is only supported by data from Swedish and Danish conscripts.[16] Thirdly, it seems that the increase in IQ is largest in the lower half on the normal distribution,[17] which means that average IQ is rising not because there are more people on the higher end of the distribution, but because there are less in the lowest. According to the nutrition hypothesis, this is so because there are less and less people suffering from serious malnutrition. Finally, there are two genetic hypotheses proposed to explain the secular increase in IQ: one emphasizes the parallel increase in IQ, brain size and the prevalence of myopia, and argues that their common cause is increased visual stimulation, while the mechanism through which the change occurs is genomic imprinting, a Lamarckian process.[18] The other genetic explanation claims that the Flynn effect is due to heterosis, the mating between relatively distinct populations with therefore different DNA, which has become more widespread in the 20th century than ever before.[19]

[14] R. B. Zajonc and P. R. Mullally, "Birth Order: Reconciling Conflicting Effects", *American Psychologist* 52 (1997), pp. 685–699.

[15] E.g. R. Lynn, "A Nutrition Theory of the Secular Increases in Intelligence – Positive Correlations between Height, Head Size and IQ", *British Journal of Educational Psychology* 59 (1989), pp. 372–377; R. Lynn, "In Support of the Nutrition Theory", in U. Neisser (ed.), *The Rising Curve*, pp. 207–215.

[16] J. M. Sundet, D. G. Barlaug and T. M. Torjussen, "The End of the Flynn Effect? A Study of Secular Trends in Mean Intelligence Test Scores of Norwegian Conscripts during Half a Century", *Intelligence* 32 (2004), pp. 349–362; T. W. Teasdale and D. R. Owen, "A Long-Term Rise and Recent Decline in Intelligence Test Performance: The Flynn Effect in Reverse", *Personality and Individual Differences* 39 (2005), pp. 837–843.

[17] R. Colom, J. M. Lluis-Font and A. Andrés-Pueyo, "The Generational Intelligence Gains Are Caused by Decreasing Variance in the Lower Half of the Distribution: Supporting Evidence for the Nutrition Hypothesis", *Intelligence* 33 (2005), pp. 83–91.

[18] M. Storfer, "Myopia, Intelligence and the Expanding Human Neocortex: Behavioral Influences and Evolutionary Implications", *International Journal of Neuroscience* 98 (1999), pp. 153–276.

[19] M. A. Mingroni, "The Secular Rise in IQ: Giving Heterosis a Closer Look", *Intelligence* 32 (2004), pp. 65–83.

The Role of Technology I: The Flynn Effect

Since readers of the present volume might be more interested in the possible role technology can play in the secular increase of IQ, I shall examine this possibility in greater detail. The role of modern cognitive technology in the secular increase in IQ has been studied most thoroughly by Patricia Greenfield and colleagues. She wrote in 1998 that her "search for the mechanisms to explain the relatively large rise in nonverbal IQ focuses on communication and information technologies: film, TV, video games, computers. … the spatial and iconic imagery featured by such media has been getting increasingly important."[20] In many countries mobile phones have become at least as widespread as computers, especially in the last decade, so they can plausibly be added to the list above.

Greenfield and her colleagues have demonstrated in a series of empirical studies that technology – primarily computer technology – can have a lasting effect on visuospatial skills, and also that playing a visual computer game shifted the participants' representational style from verbal to iconic. Moreover, they found this effect only when the game was played on a computer screen, but not when it was played on a board; hence the medium itself had a causal role. They concluded that "most computer applications have design features that shift the balance of required information processing from verbal to visual".[21]

She also argues that the slower increase in verbal IQ and the actual decline of verbal SAT[22] scores are the results of modern technology as well. Besides shifting the dominant representational style from verbal to iconic, these media, and especially television, have resulted in people reading less in general and reading less newspapers in particular. Verbal IQ tests typically measure vocabulary and the comprehension of relatively complicated written texts – both are hindered by the dominance of commercial television in informing people. More recently, however, she draws attention to how this might have changed with the spread of internet use: "Unlike the medium of television and video / computer games, the internet involves reading print and it may actually result in more read-

[20] P. M. Greenfield, "The Cultural Evolution of IQ", in U. Neisser (ed.), *The Rising Curve*, pp. 81–123.

[21] A. E. Maynard, K. Subrahmanyam and P. M. Greenfield, "Technology and the Development of Intelligence: From the Loom to the Computer", in R. J. Sternberg and D. Preiss (eds.), *Intelligence and Technology: The Impact of Tools on the Nature and Development of Human Abilities*, London: Lawrence Erlbaum Associates, 2005, p. 32.

[22] A standardized test for college admissions in the United States.

ing than before, albeit reading in a different medium."[23]

Greenfield summarizes other experimental studies as well, showing a beneficial effect of knowledge on, and use of, technology on cognitive abilities. In one study of a technical training school in Uganda, performance on nonverbal tests improved after two years of technical training, whereas performance on verbal tests remained intact. In another study it was found that playing Tetris improved performance on tasks similar to the ones that appear on nonverbal IQ tests, but only in males. Recall that one of the genetic theories of the Flynn effect (see above) also claims that it is the visual environment that triggers the genomic imprinting, which in turns leads to increased IQ, brain size and myopia.

Maynard, Subrahmanyam and Greenfield, in a more recent paper[24] summarize the results of numerous empirical studies and conclude that there are three ways computer game playing can have an effect on cognition. The message to take home is not that visual computer games improve visual attention per se, but rather that – as the authors themselves emphasize – "these skills are crucial … to the internet and many other computer applications"[25] as well.

The first one is the improvement of divided visual attention, or parallel visual processing. The second is mental transformation, a skill necessary to solve items on many tests of visuospatial IQ. The third is the shift of representation from verbal to spatial and iconic, meaning not only that participants created more iconic representations after being exposed to computer games, but also that they showed a better understanding of this type of representation afterwards. This was already emphasized in Greenfield's account of the Flynn effect: "Film, television, video games, and computers all privilege iconic, or analog representation over symbolic, or digital representation. That is, they privilege image over word. … Iconic images and diagrams are basic to all nonverbal performance tests. If modern computer technology is making people more iconic in their style of representation, it follows logically that people will do better on nonverbal IQ tests."[26] One might add that mobile phones usually provide the same focus on iconic representation compared to verbal representation.

One serious flaw of the technology hypothesis of the Flynn effect, however, is that there is no evidence indicating a correspondence between the spread of computers, mobile phones and similar, cognitively demanding technology on the one hand and the magnitude of the Flynn effect on the other.

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[23] Maynard et al., *loc. cit.*, p. 41.

[24] *Ibid.*, pp. 29–53.

[25] *Ibid.*, p. 32.

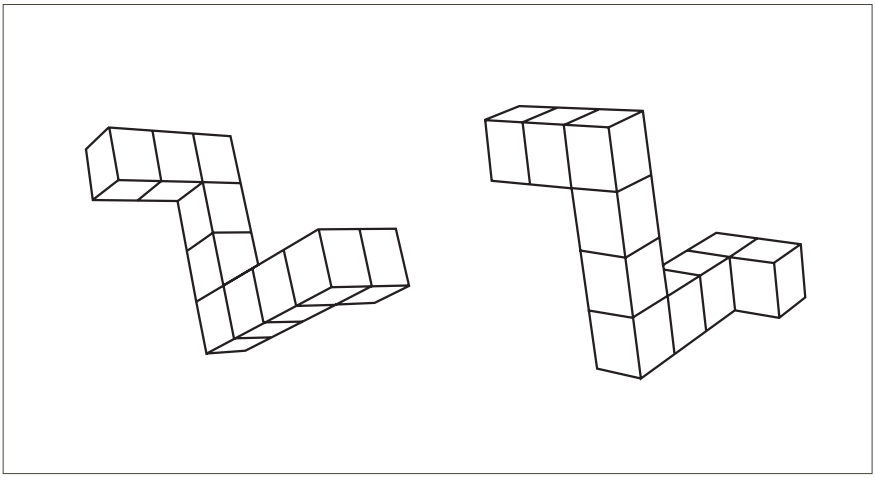

Figure 2
Mental rotation task, similar to the items appearing in spatial IQ tests. The task is to decide whether the two figures can be rotated into one another.

The Role of Technology II: Concepts of Intelligence

So far it has been discussed how technology, and especially visual cognitive technology can have an impact on the Flynn effect, i.e. can cause a *quantitative* change in IQ. However, technology can change not just how well we perform on tests that measure our present conception of intelligence, it can also redefine our notion of what intelligence is.

The definition of intelligence has always caused controversy. There are many theorists who argue that there is no culture-independent conception of intelligence, and therefore any measure of intelligence is permeated by the given culture's notion of what constitutes intelligent behaviour.[27] It is not a new idea that communication technology can have an enormous effect on cognition.[28] In particular, it has been argued that lit-

[26] P. M. Greenfield, "The Cultural Evolution of IQ", *loc. cit.*, pp. 99–103.

[27] E.g. S. H. Irvine and J. W. Berry, *Human Abilities in Cultural Context*, Cambridge: Cambridge University Press, 1988.

[28] See Tamás Demeter, "History of Ideas and the History of Communication: A Lesson for Research on the Cognitive Consequences of Mobile Communication", in Kristóf Nyíri (ed.), *Mobile Understanding: The Epistemology of Ubiquitous Communication*, Vienna: Passagen Verlag, 2006, pp. 31–40.

eracy can foster abstract thinking,[29] and that computer applications trigger different cognitive abilities than those required for understanding printed materials.[30]

Following this line of argument there are theorists who claim that technology can change our conception of intelligence. Preiss and Sternberg, for example, claim "that a psychological consideration of technology can expand our view of intelligence as dynamic, culturally shaped, multiple and distributed".[31] Or, as Greenfield argues: "The nature of a culture's tools at a particular time influences that culture's operational definition of intelligence. That is, the cognitive skills required to develop and utilize a culture's tool set become an important component of a group's implicit definition of intelligence, [as well as] using a particular tool set develops the cognitive skills that are part of a group's implicit definition of intelligence."[32]

Salomon and colleagues[33] make a distinction between what they call the effects *of, with* and *through* technology. Effects *with* technology mean cognitive amplification that lasts only as long as one is operating the given tool, effects *of* mean development that lasts after the use of the tool, whereas effects *through* mean that technology not only enhances performance but reorganizes it. In this sense the Flynn effect can be partly an effect *of* technology, while our changing conception of intelligence is an effect *through* technology.

Even if we restrict our concept of intelligence to academic intelligence, i.e. the kind of cognitive skill that predicts school achievement, that can be altered by technology as well. It seems entirely possible that in the long run, when the use of cognitive technology will be a general practice in schools, overruling the current dominance of printed materials, the content of IQ tests will have to predict skills to apply these tools as well.

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[29] E.g. A. R. Luria, *Cognitive Development: Its Cultural and Social Foundations*, Cambridge, MA: Harvard University Press, 1976; P. M. Greenfield, "Oral and Written Language: The Consequences for Cognitive Development in Africa, the United States and England", *Language and Speech* 15 (1972), pp. 169–178.

[30] E.g. P. M. Greenfield, *Mind and Media: The Effects of Television, Video Games and Computers*, Cambridge, MA: Harvard University Press, 1984.

[31] D. Preiss and R. J. Sternberg, "Technologies for Working Intelligence", in R. J. Sternberg and D. Preiss (eds.), *Intelligence and Technology*, p. 185.

[32] Maynard et al., *loc. cit.*, p. 29.

[33] G. Salomon and D. Perkins, "Do Technologies Make Us Smarter? Intellectual Amplification With, Of and Through Technology", in R. J. Sternberg and D. Preiss (eds.), *Intelligence and Technology*, pp. 71–86.

Concluding Remarks

There is probably no single, universal cause of the Flynn effect. Being a historical phenomenon, when it comes to choosing between rival hypotheses explaining the Flynn effect, one can only rely on indirect aspects. Experimental studies can establish a causal connection between a given factor and IQ, and thereby identify probable candidates for a causal explanation, but this still does not prove that the given factor had a causal role. It seems very likely that there are multiple causes, and nutrition, as well as changes of the educational system and the size of the average family are all likely candidates. Technology, including mobile phones, may play an important part, too, especially with regard to the improvement of visuospatial skills. Such tools can also change the way we conceive intelligent behaviour, and if they find their ways to the school curriculum, they can even change the narrowest concept of intelligence as a predictor of educational achievement.