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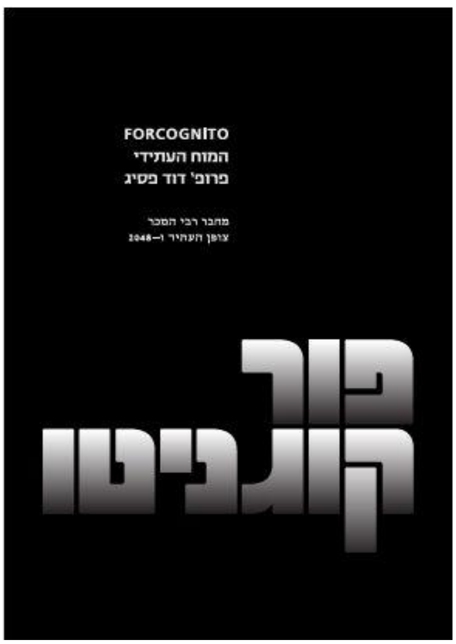

Part III

ENHANCING INTELLIGENCE

Translated by Tamar Cohen

A great many people think they are
thinking when they are merely rearranging
their prejudices.

William James

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Accelerated Enhancement of Average IQ Level

Many have been burdened in recent years by a growing anxiety that the human species is in such an accelerated state of intellectual decline that we may have reached the point of no return. Some are alarmed by their children and grandchildren's low scores on international standardized tests, for which many blame the deterioration of the school system[1] or new technologies, which are making our children physically and mentally lazy and ignorant.[2] Every once in a while a new study is published, making waves in the media and feeding these anxieties. These studies became especially popular with the spread of access to the Internet via portable and wireless apparatuses, from smart phones to tablet computers. The notion of the decline of the human species has in fact been seared in many people's consciousness as a *fait accompli*; for these people, all that remains to be done is to lament the coming generations or to organize urgently to rescue what can still be salvaged.

The notion of the decline of the human species has been seared in many people's consciousness as a *fait accompli*.

This section of the book sets out to allay such fears and to strengthen this book's claim that the human brain is in fact in the midst an accelerated process of improvement, which includes the capacity to generate long-term future thinking.

I admit that I was also depressed for some time by study after study forecasting our decline. But at a certain point I began to doubt the reliability of these studies, and I decided to examine the matter for myself. I found that many of the studies suggesting a decline in our children's cognitive skills examined insignificant variables or short-term abilities, such as general knowledge or task attention. So I began to search for studies that tracked the issue of human intelligence over many years, in order to see whether their findings supported the same conclusions.

How surprised I was to discover the personal story of a scholar by the name of James Flynn, who has been conducting studies on IQ for more than fifty years. I was curious as to why I did not know of his work, and how it was, in all my years of study, that no one had bothered to mention the issues that he had been pondering for decades. After reading his studies, I decided to mobilize my students and the Virtual Reality Lab which I head, in order to examine whether and how we can improve a large variety of cognitive skills.

The Flynn Effect

James Flynn was born in 1934 in the United States and today is an energetic emeritus professor at the University of Otago in New Zealand. Flynn has published many books, but he became known primarily thanks to a discovery that has become known, eponymously, as the Flynn effect.

When he was seventeen years old, in 1951, Flynn left his native Washington for the University of Chicago to study political science. Extraordinarily, the young Flynn finished his Bachelor's Degree in just one year, receiving his degree at age eighteen. After that he went on to complete his Master's and Doctoral degrees. Nine years prior to the beginning of his studies, a few students at the University of Chicago had founded the Congress of Racial Equality (CORE), and as a student, Flynn joined the organization.

In the early 1950s, at the height of the struggle for civil rights in the United States, Flynn received his first academic post at the University of East Kentucky. In his first years as professor, as the eyes of many on the senior staff were examining his application for tenure, he was also appointed chairman of the local branch of CORE. There he expressed his views about the nature of IQ and the equality between the races, which he had derived from his studies on this contentious issue. Needless to say, the tenure committee did not grant him a promotion, and he had to find a different place of work. He went to teach at Lake Forest College in Chicago, and there he understood once and for all that his research and his socialist opinions would not ensure him a tenured academic position in the United States. In 1963 he left the United States for New Zealand, where he joined the faculty at the University of Otago and began to study the history of IQ in order to see whether and how it had changed over the years.

In the 1980s, after more than a decade of research, Flynn published his first book. In the book, entitled *Race, IQ and Jensen*,[3] he laid out his claim that the reason African-Americans have lower IQ scores than whites is not a result of genetic inferiority, as leading scholars of intelligence, including the well-known Arthur Jensen,[4] were claiming at the time. He claimed that the gap in IQ was due to the disparity in the living conditions of the two groups, and therefore, and more importantly, that this was a gap that could be bridged. In his book, Flynn presented data from IQ tests conducted by the US Army on conscripts between the two world wars. Using this data, he pointed to the fact that in this period, the African-American conscripts narrowed the gap with their white counterparts.

In the period between the world wars, African-Americans closed the IQ gap with whites.

Not surprisingly, his work caused a storm among conservative politicians and scientists, and many began to attack his findings as well as his motivations. More objective critics pointed to the fact that the US Army tests tested general knowledge from high school, and that had the African-American conscripts been tested with purely cognitive tests that were not based on acquired knowledge, the gap in IQ between them and the whites would have remained.

In order to properly respond to his critics, Flynn would have to demonstrate that the US Army tests indeed measured inborn intelligence and not just acquired knowledge. He looked at the two most commonly used IQ tests in the interwar period in order to see to what degree they corresponded with the tests that the US Army administered in the same years. The two IQ tests, Stanford-Binet and Wechsler, were considered then (in their original versions) and to this day (Stanford-Binet 5), to be reliable measures of innate intelligence. Flynn's assumption was that if the same subjects received similar scores on the IQ tests as they did on the army's tests, this would strengthen his claim that the African-American population that was drafted into the army between the two world wars had indeed improved its IQ level.

To his chagrin, he did not find a correlation between the results obtained on the IQ test and those in the US Army tests. He was, however, struck by something else. He noticed that new terms were periodically introduced into the IQ test to replace obsolete ones. For example, words such as "typewriter" were replaced by "computer." He also noticed that whenever the terms were updated, one control group would be tested on both the old and the new versions, in order to make sure that they got similar scores on both tests.

For the sake of accuracy, the writers of the tests would publish the scores of the control group in both the old and new version, in the IQ score calibration guides. In the data, he remarked that the control group almost always received a slightly higher score on the old version of the test. Given that IQ score is an indication of the intellectual ability of the subject in comparison to a representative demographic sample of people, in effect, Flynn demonstrated that the people who calibrated the tests were unintentionally creating new versions that were slightly more challenging for the representative sample.

With these findings in hand, Flynn found himself confronting an even more provocative hypothesis. Instead of asking how and why one underprivileged group, such as the African-American population in the United States, had improved its cognitive abilities, he began to wonder if the average person in general was becoming smarter over the years. He set out to analyze every study ever conducted in which one person was tested with both IQ tests. By 1984 he had collected and processed data from studies done on about 7,000 subjects, who had been tested in about a dozen different combinations of cognitive tests. His conclusions were dramatic. He found that the white population in the United States consistently improved its IQ scores at a rate of 0.3 points per year over the course of fifty years.

In 1984, Flynn presented his findings in an article.[5] But his critics were not convinced. They claimed that he had merely shown that improvements in the school systems might have improved the IQ scores, and that the reliability of IQ scores as a measure of innate intelligence was less than originally thought. The commonly accepted paradigm in those days generally favored nature over nurture and assumed that IQ scores remain basically stable throughout the adult years of a person's life. This paradigm was reinforced by tests administered to twins who had been separated at birth. The results of these tests demonstrated that their genetic make-up was stronger than environmental influences. Even though the data pointed to such a fast

The accepted paradigm in those days generally favored nature over nurture.

improvement in the intelligence among the white population, it still did not convince his critics. It just simply wasn't logical to them, and they didn't let the facts confuse them.

But Flynn was not one to give up easily. After the fame he had received from his 1984 article, he began to request data from military institutions in many countries that had conducted intelligence tests on their conscripts, and from Test-writing institutes around the world that develop IQ tests. Of course, not everyone responded to his request, but there were many who did. Flynn recalls that one answer in particular, which he received on a Saturday in November 1984, convinced him once and for all that he was on the brink of a unique discovery.

The letter, which he received from the Dutch psychologist P. A. Vroon, included results from Raven's Progressive Matrices tests, which had been administered to eighteen-year-olds who were drafted to the Dutch army between 1952 and 1982. The Raven test is considered to this day to be one of the most reliable measures of inborn intelligence. In the test, the subject must identify logical patterns in groups of shapes and to fill in the blank. The test has no words, and there is no connection to prior school learning or prior general knowledge (see fig. 23). The letter stated that the conscripts' scores on the Raven test rose by twenty points on average in the thirty years between 1952 and 1982.

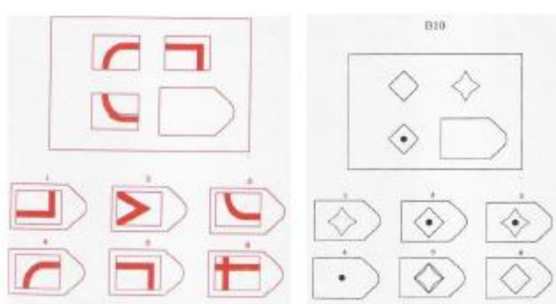

Fig. 23. Examples from Series B of Raven's Colored Progressive Matrices Test (Raven, 1965)

These scores showed a significant improvement; an eighteen-year-old with a median score on the Raven test in 1982 received a score that was twenty percent higher than an eighteen-year-old who took the same test in 1952. Flynn went on to receive data from thirteen additional countries, and all of them pointed to an enhancement in IQ scores.

Today the results are so clear cut that they are almost incontrovertible, pointing to a consistent rise in IQ scores throughout the twentieth century. About thirty of the nations, some more and some less developed, among them Israel, from which Flynn got his data, noted an improvement in IQ scores. Not only that, but his latest studies also point to the fact that the rate of improvement is rising. The average annual improvement measured between 1947 and 1972 was 0.31 IQ points, while in the 1990s the improvement grew at a rate of 0.36 points per year.

His latest studies also point to the fact that the rate of improvement is rising.

We already hold the proof that the world is becoming more intelligent, but this has raised many dilemmas and much bewilderment. How does it happen? What is the meaning of the data? What are the implications of the phenomenon?[6] The paradoxes began to pile up. For example, Flynn calculated and found that if we back-cast the data to 1900, the average score on the IQ tests would be 70 in early-twentieth-first-century terms—a score bordering on mental retardation, Flynn claimed. If people in the year 1900 were so deficient, how did they manage to conduct a modern society?

But the strangest thing of all was how such a significant improvement had occurred with such great speed. All of the signs showed that IQ was an inborn genetic trait: parents and children generally reveal similar IQ levels; identical twins produced closer scores than fraternal twins; and achievements in IQ tests that resulted from practice or learning, tended to dissipate over time. Nonetheless, the improvement noted over the fifty years during which the tests were conducted—on a large scale and in numerous countries—suggested that there was something very significant that had apparently created this accelerated effect.[7] But most of all, everyone asked: how can environmental factors be so powerful and yet so ambiguous?

Flynn and many others have been dealing with these questions for two decades. There were those who opposed the very notion of measuring IQ, claiming that this index was questionable from the outset. They claimed further that it serves those who espouse eugenics, giving them an ostensibly empirical stamp of approval for discriminatory behavior. But Flynn was sure that IQ was an important index. Many studies showed that IQ very reliably predicts success in academic studies. Different studies found that the IQ scores correspond with teachers' opinions about students, and very few people were found who had a high IQ and nonetheless worked in professions that did not demand creativity or autonomy. It was clear that many elements were necessary to succeed in life, but a higher-than-average IQ score was always found to be a predicting factor.

Among those who took the idea of IQ enhancement seriously, there were those who attributed it to the improvement in children's nutrition. There were those who hypothesized that family size had a crucial influence, and there were those who believed that the school system and the liberal values of modern culture were contributing factors. But no empirical evidence was found to support the scope and speed of the phenomenon. No theory or hypothesis was found that could explain the pattern of improvement. Most IQ tests include a series of sub-tests, wherein each one tests a different cognitive skill. The problem is that there was significant improvement only in one particular type of sub-test. The average person improved his scores in tasks such as: identifying and completing geometric patterns, locating abstract similarities between objects, and reorganizing mixed up pictures to tell a logical story. On the other hand, no improvement was shown in the ability to remember sequences of numbers or, in particular, in vocabulary and general knowledge.

No empirical evidence was found to support the connection between the scope and speed of the phenomenon and variables such as nutrition, family size, education, and liberal values.

It may be possible to explain why children who had received better nutrition, children who had fewer siblings, or even children who were educated in a more open and liberal environment, might improve some of their cognitive abilities even as adults, but the phenomenon was also found among subjects who did not have proper nutrition, who grew up with many brothers and sisters, and who did not receive a liberal education.

While the various components of the IQ tests measure different skills, generally speaking, one who gets a high score in one part will succeed in many other components as well. For example, one who gets a high score in pattern recognition will also succeed in math. He will generally demonstrate knowledge in a wide range of subjects and will have a correspondingly large vocabulary. In the study of intelligence, this phenomenon is known as the "g-factor."

This term was coined by Charles Spearman[8] in order to explain the significant correlation between scores in the different parts of the intelligence tests. One might expect that one kind of skill would come at the expense of another, for example, because the first takes up a large part of the brain's neurophysiologic activity, or because exercising one field might come at the expense of others. It turns out, however, that there is a correlation between all of the various intelligence indices. Spearman developed statistical methods (such as parallel factor analysis) to organize the multi-faceted information about intelligence. He called the main axis of data the g-factor, or the general intelligence factor. Ultimately this is what the IQ test is meant to measure.

True, there are certain sub-tests that better reflect a given ability, and this may not have a connection with the overall abilities. For example, let us imagine an index by which we can measure people's ability to cook. It would be reasonable to claim that those who cook one dish successfully will cook other dishes at a similar level. One could therefore say that there is such thing as a "general cooking factor." However it would also be reasonable to assume a greater gap between excellent chefs and the rest of the population of cooks when preparing a soufflé, for example, than when preparing an omelet.

Similarly, the more complex cognitive tasks should also be the better predictors of the g factor. Paradoxically, however, the tests from many countries that Flynn checked showed a significant improvement in the complex tasks, while in the simpler tasks there was no improvement (See fig. 24). Here was the enigma: if every pair of sub-tests should similarly reflect inborn intelligence, how was it that people improved their abilities in one and not at all in another?

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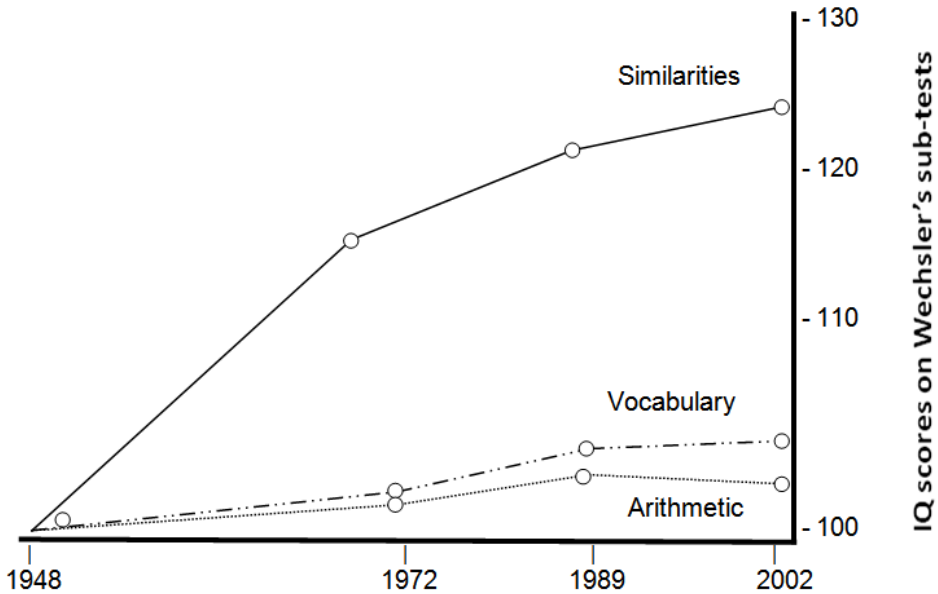

Fig. 24. IQ scores on Wechsler's sub-tests, measured longitudinally over the course of five decades

These inconsistencies in the enhancement in IQ scores prompted Flynn to search for different explanations. Others would subsequently propose yet other explanations. Following is one of the main explanations that Flynn gave for the phenomenon, which came to be known as the Flynn Effect. In order to illustrate his explanation he often gave examples from the world of sports. Let us assume, he said, that we exposed our children to a series of athletic challenges, such as long jump, high jump, long-distance running, and more. There would certainly be connections between their various athletic abilities just as there is a correspondence between mental abilities. Those who can run fast will also be able to jump higher. Thus we would also calculate a general physical-fitness factor.

But over time, priorities changed, he continued. Satellite television broadcasts became more common, advertisers found that certain events attracted greater audiences, and they began to sponsor athletes who excelled in these events and not others. Let's say that the one-hundred-meter dash became the most popular track-and-field category in many schools and sports clubs, and so training for it improved. Although the human body and genome did not change, Flynn emphasizes, and despite the fact that excellence in the one-hundred-meter dash is still related to excellence in any other sport activities, the achievements in this category improved significantly, while achievements in other categories hardly improved.

In his opinion, through back-casting, one can say which mental preferences have changed over the last century. It seems that in contrast to our parents' and grandparents' generations, we attach more importance to the ability to find abstract similarities between objects. For example, in the question: What do dogs and rabbits have in common? We would expect the answer to be: both are mammals. We are also better at applying our logic to find abstract patterns, as in the Raven tests.

Thus, Flynn began to solve the riddle of how to account for such a great improvement in certain sections of the tests. He explained that while we may not be more intelligent than our parents; we have learned to apply our intelligence to a new set of problems. According to him, we disconnected our logic from the concrete world and came to prefer the hypothetical, and we came to think of the world as a place that should be classified and understood scientifically, rather than as a place that should be influenced in concrete ways.

In Flynn's opinion the astounding improvement in IQ stems from societal preferences that tended away from concrete logic toward scientific logic.

This kind of explanation raised many questions for researchers. Some[9] claimed that this explanation was too simple. According to them,[10] connecting this amazing improvement in mental abilities exclusively with the redirection of societal preferences from concrete logic to scientific logic, renders the entire effect uninteresting and certainly not so important. According to them, with such an explanation, we might miss the potential hidden in the discovery itself. Changes in preferences or tastes are real and significant, just like the speed with which we process our thoughts or the amount of information we can hold in our memory.

While the improvement in test scores is not necessarily the result of enhanced intelligence, Flynn clarifies, the phenomenon is nonetheless an important one. He often shares his observations of his grandchildren as a proof of his explanations. Thirty years ago, he claims, when parents read their children a story, and the child would point to the picture of an animal and say: "a cow," they would answer him by saying: "yes, that is a cow." By contrast, today when a child says: "a cow," the parents immediately say: "what does the cow say? How many legs does it have?" and so on and so forth. According to him, this kind of interaction trains the children for a different level of abstract thinking from that which children were required to demonstrate in previous generations. This exercise, so common in the social environments of children in the last decades, is the primary reason for the improvement in scores in the specific sub-tests that specifically measure abstraction.

But this explanation leaves one aspect of the riddle unsolved. It does not explain why environmental variables have only a minor influence when comparing between children of the same age, but become more influential when measured over time. For this, too, Flynn has an explanation, which he says he reached in the wake of his collaboration with William Dickens,[11] an economist at the Brookings Institute in Washington, DC. According to Flynn, the performance level of genes rises significantly when they are given the opportunity to be expressed or when they are immersed in an enhanced environment.

In order to illustrate this matter, he once again uses a sports analogy—this time a tale about identical twins who were separated at birth. These twins were born, let's say, in Indiana and were adopted immediately following their birth by two families that live near one another but don't know about one another's existence. Let's say that these twins' genes make them taller than the average child their age. It is known that Indianans are crazy about basketball, and like all children, the twins also play basketball. Because they are taller and stronger than average, they are the best in their respective neighborhoods. Since they like the game, they play more and more, constantly improving their skills. Each of the twins becomes a player on their school team, works with good coaches, practices a lot, and eventually continues to play on his college team. According to Flynn, even the tallest and strongest individuals will be bad basketball players if they never train. What makes them excellent players is the fact that their genes take advantage of a supportive environment in order to realize their innate potential.

According to Flynn, this analogy explains the riddle in its entirety. In effect, he says, there is no riddle; this is the first time in human history in which a small number of people with enhanced mental abilities create enhanced mental environments for many others. As social

This is the first time in human history in which a small number of people with enhanced mental abilities has created enhanced mental environments for many others.

creatures, human beings participate in the smart environments created by a few intelligent people. Before the twentieth century, only the very few had access to complex ideas. Today, when one person has a good idea, the idea spreads quickly and becomes part of the public domain. This notion of the public domain has changed everything.

According to Flynn, this proliferation of ideas does not have to be "intellectual" in order for it to influence intelligence; it can be social or even of entertainment value. Stephen Johnson described this nicely in his book *Everything Bad is Good for You*,[12] in which he examines the way in which popular culture has changed as more and more people learned to use their brains with speed and logic. Computer games such as *Civilization* and *Sims* reward players who obey the internal logic of the virtual worlds they create. Popular television series weave together many characters in multiple plots that move in parabolic narratives spreading over episodes, seasons, and years. It is sufficient to think of a few television series, such as *24* or *Heroes*, to see how viewers must retain many unanswered questions over the course of entire series.

But there is no doubt that the Flynn effect is not all rosy. There are also clear signs that children do not have certain experiences that help them develop certain cognitive skills later on. This is the source of the social and political outcry about intellectual decline from generation to generation. Michael Shayer, [13] a psychologist from Kings College in London, who invested most of his career in studying the foundations of mathematical thinking, is considered to be at the forefront of this cry. As far back as 1976, Shayer examined children's levels of comprehension of basic concepts of volume and form, which are commonly believed to be at the base of future mathematical skills. When he repeated these tests in 2003, he found that eleven-year-old children had regressed to the level that eight-year-old children were at thirty years earlier.

Notwithstanding, one must agree that Flynn's explanations do manage to circumvent the futile debate about nature vs. nurture. At the very least, he provides answers to his initial questions: why do African-Americans receive lower scores on IQ tests than whites, even if you compare groups of African-Americans and whites of similar socio-economic background or any other variable. According to him, it is reasonable to assume that in a society that holds prejudicial and biased opinions, African-Americans choose to live together, and their genes co-opt as a result primarily to degraded living, learning, and occupational environments.

The important thing that arises from Flynn's explanations is that all societies on earth have the capacity to improve their mental skills. According to Flynn, now that we have improved our IQ scores, the next step is to improve our abstract understanding of important concepts for the coming century, such as "human capital, "placebo," and "control group." If we were only capable of teaching our children to use these concepts properly, he claims at every opportunity, we would give them essential intelligence that will help them better determine what is real in the world around them. According to him, the brain is flexible, and the Flynn effect shows that what we value most will improve.

Nobody knows whether the enhancement in IQ that the Flynn effect identified will continue, but there is no doubt that it has marked the twentieth century. And, as far as we know, it continues to have an influence into the twenty-first century.

Only the extremely ignorant or the
extremely intelligent can resist change.
Socrates

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Using Technology to Enhance Cognitive Skills

On the one hand we have Flynn's explanations and the eponymous Flynn effect, with its optimistic prognosis for the human species, and on the other hand we have those studies that point to a regression in other skills and posit doomsday scenarios about the decline of human intelligence. This apparent contradiction has not ceased to preoccupy me over the last decade. I suspected that there was something much more significant at play here than just practice and learning, and that we were still far from understanding the source and meaning of the improvement in IQ scores. And so I set to work, along with my master's and doctoral students in the Virtual Reality Laboratory, to test a few aspects of Flynn's social and cultural explanation for the overwhelming improvement in IQ test scores. I wanted to test whether it was possible to generate an even greater acceleration in the enhancement of various abstract thinking skills. Was it possible to improve skills among populations with congenital cognitive disabilities as well? What was the most efficient way to accelerate the improvement? And most importantly—I wanted to examine whether it was possible to improve concrete thinking skills as well, which Flynn found not to have improved in the fifty years of his study.

Our studies examined two things: first, whether it was possible to enhance skills among people with various congenital disabilities and to assess whether or not the improvements were the sole result of accelerated environmental improvements, as Flynn claimed. If children with Down Syndrome, for example, could quickly improve the cognitive skills in areas in which they are considered deficient, we could postulate that the improvement was not related to some cultural or environmental factor, but to something else. The second thing that I wished to examine was whether it was possible to improve skills other than abstract skills, among varied test groups. If the subjects would significantly improve their conceptual analogy skills, which are classified by Flynn as concrete thinking, then we could say with greater confidence that something else was at work.

For years I suspected that there was something in the technologies available to us that was responsible for the fast pace of this enhancement, if not for the enhancement itself. In order to examine this, I hypothesized that by using three-dimensional technology that was not yet in common use among the subjects, I would be able at least to identify correlations between technology per se and the improvements in IQ test scores, and thus to ground the hypothesis that it is not in fact the natural living environment which is behind the improvement. I assumed that if the short-term use of a technology that was not found in the subjects' everyday environments could accelerate the improvement in the tested cognitive skills, we could solidly cast doubt on Flynn's explanations. The 3D technology I am referring to is Immersive Virtual Reality (IVR) as experienced with a Head Mounted Display (HMD) (fig. 25), which renders what is seen on the computer as an interactive and immersive three-dimensional experience. Following is a sample from the studies we have published in the last decade. I believe that the results raise serious questions about Flynn's explanations.

There is something in the technologies available to us that is responsible for the fast pace of this enhancement, if not for the enhancement itself.

Fig. 25: Head Mounted Display – HMD

As far as I can understand, the Flynn effect could point to something much more significant than we realize. It seems that today's technologies, with their advanced interfaces, could generate an accelerated enhancement in a wide range of cognitive skills that the natural environment alone cannot account for. Thus, I believe, we are yet to grasp its origin and scope.

Virtual Reality and Intelligence Enhancement

In order to begin to examine whether 3D Immersive Virtual Reality (3D IVR) technology is capable of significantly enhancing cognitive skills, we designed three tiers of experiments. The first tier included experiments that tested the hypothesis that there is a clear-cut benefit to using virtual reality for learning concepts that could only be taught in the past through verbal means. The initial goal was simply to see whether advanced technologies could significantly accelerate learning processes. The second tier included a group of experiments in which we examined whether it was possible to improve not only the level of awareness and sensitivity to the other with the help of IVR, but also whether it was possible to improve cognitive skills that can be measured through standard intelligence tests. The third tier included a few experiments in which we examined whether it was possible to improve IQ scores even for those with lesser genetic potential. Most importantly, we examined if it is possible to improve cognitive skills among normative populations.

Three tiers of experiments.

If these three levels pointed to clear-cut and significant cognitive improvements, then it would be possible to claim, in contrast to Flynn's explanations, that there is another factor at work besides natural environment. I suspected that we were holding a new kind of fire, whose implications we do not entirely understand; and that the improvement in IQ that it causes is only one of many things that is has yet to generate.

First Tier: Improving Comprehension of Difficult Concepts

Getting into the Head of a Toddler

In one of our first studies, we tried to examine whether it was possible to teach adults how toddlers think and how they see their environment.[14] We wanted to test whether it was possible, in a short time, with the help of IVR, to improve preschool teachers' comprehension of the cognitive state of the toddlers when they come to daycare and have to separate from their parents for the first time.

At the beginning of the year the nursery school teacher carries a great responsibility. She must receive a large number of excited and emotional toddlers; she must calm them down, give them emotional support, care for their physical needs, be patient, and project calm and tranquility while surrounded by the crying of many of the small children. In order to show sympathy and patience, the caregiver must be aware of the cognitive experiences of the toddler and also to empathize with his emotional state during the first days in daycare. Many hours of academic training are spent preparing teachers and caregivers for this situation, and nonetheless, in many cases the training does not affect the behavior of the toddlers. Studies have shown that teachers function better with time, but this is after many years of experience and ongoing academic training.

In this study we used IVR to illustrate in just a few minutes the experience of the toddler on his first day in daycare.[15] The assumption of the research was that after this experience, the caregiver would be able to better understand how the toddler experiences the transition from the home to the new nursery school environment, and that she will function better accordingly.

The virtual world that we developed simulated the toddler's experience from his cognitive and emotional point of view. We built this world based on the theories of well-known scholars, among them Piaget[16] and Erikson.[17] These researchers found that a toddler from age eight to twenty-four months sees the world in a unique way.

According to this literature, toddlers' cognition is characterized by a phenomenon known as "object permanence." According to Piaget, until eight months, the baby thinks that if an object disappears from sight, it no longer exists. Towards the twelfth month of his life the toddler begins to look for hidden objects, and to search in the spot where the object was hidden, if he saw it being hidden. Only towards twenty-four months does the toddler learn that objects that are not seen continue to exist. As a result of this developmental process, the toddler experiences a feeling of instability over the course of the first two years of his life; he lives in a world in which objects and people appear, disappear, and reappear without him understanding why or how. The toddler lives with a feeling of lack of control of his environment, and this is apparently the reason why toddlers cry so heartbreakingly in their first days at daycare, when they separate from their parents. For them a parent that is not seen is a parent who has disappeared entirely and will not return.

In order to improve the teachers' comprehension of the toddler's consciousness, we developed a three-dimensional IVR that the caregiver can enter through a Head Mounted Display (HMD) (fig. 26). In order to simulate the cognitive experience of object permanence, we asked the caregivers to perform various tasks in a world that is governed by the following logic: any object that they hold in their hand and put down for a moment disappears and can't be seen again. In this way we illustrated the cognitive and emotional state[18] of toddlers from age one to two years.

Fig. 26. A nursery school teacher experiencing the world of toddlers

The study's sample included forty teachers and caregivers who work with toddlers aged six months to four years, in private frameworks such as family daycare and private nursery schools. The findings, as we assumed, showed that the teachers' awareness of the cognitive and emotional experiences of toddlers improved definitively in tests that were administered after the experiment, in comparison with the scores they received beforehand. Most of them told us later on that this awareness of the cognitive and emotional experiences of the toddlers improved the way in which they took care of the children in the first days of daycare, in ways that they could not have imagined beforehand. Most of them emphasized that since experiencing the simulation of toddler cognition, they use this knowledge in the day to day care that they give.

Due to the impact of our research among nursery school teachers, we decided to donate the virtual worlds we had constructed and the equipment necessary to operate them to the supervisor of early childhood education in the ministry of education, for use in training nursery school teachers around the country. This research clearly indicated that it is possible to teach difficult concepts from the perspective of the "other" in a short time. The caregivers' improvement on test scores about the cognitive issues of toddlers came after experiencing the virtual world we created for just half an hour. In a sense, this research supported Flynn's explanations, which claim that our environment can enhance learning and the level of achievements in tests that test knowledge.

Enhancing Awareness of the Difficulties of New Immigrants

With these encouraging results in hand, we undertook to reinforce them by creating simulated environments that could improve awareness of various "others" in Israeli society. Awareness of the other is an important part of any cognitive developmental process, in particular to the development of Futures' thinking. Since such awareness is difficult to convey in purely verbal ways, we looked for a way to try to teach it in a short time. We began by checking whether technology could influence the degree of awareness of 178 seventh- and eighth-grade students of the emotional and social experiences of new immigrants in their first stages in a new country.

Israeli-born students were divided into two groups: the experimental group, which experienced virtual worlds simulating the feelings and emotional and social experiences of a new immigrant teenager; and a control group who watched a movie on the same subject. We developed an "awareness index" of the emotional and social experiences of new immigrants, through interviews with a group of male and female teenagers who recently immigrated to Israel; their answers were compared to the answers of the Israeli-born teenagers. Here, too, the results indicated that it is possible to greatly accelerate the process of understanding the consciousness of the other and to teach complex concepts in a very short time with the help of new simulation tools.[19]

Enhancement of Knowledge about Dyslexia

We then moved on to another kind of knowledge that is particularly difficult to convey through verbal means, namely, conveying the cognitive experience of dyslexia for those who are not dyslexic. This study was particularly challenging. Our literature survey revealed such a wide variety of kinds of dyslexia, and such a variety of definitions, that we almost despaired of being able to develop a 3D immersive virtual world that could simulate the experience of dyslexia. To our help came researchers Gvion and Friedmann,[20] who proposed an initial and partial scale of ten kinds of dyslexia. Based on this scale, we built ten worlds that simulate these kinds of dyslexia—visual letter agnosia, neglect dyslexia, visual dyslexia, etc.

In two consecutive studies, we assessed whether parents[21] and teachers[22] who experienced dyslexia in a simulated reality could enhance their awareness of the cognitive experiences of the dyslectic student trying to read. The parents and teachers were divided into two groups: the test group, which experienced the simulated environment of the cognitive experiences of the dyslectic student; and a control group that watched a movie on the subject of dyslexia, which explained and illustrated the different kinds of dyslexia. All of the subjects filled out questionnaires before and after the experience. The questionnaires assessed the teachers' and parents' cognitive awareness of the experience of the dyslectic student in his encounter with the written word.

From these studies we learned that parents and teachers who experienced the cognitive state of the dyslectics through virtual reality improved their knowledge on the subject significantly in comparison with the parents and teachers who learned about dyslexia through the informational film.

Enhancing Knowledge about Exam Anxiety

In order to confirm that virtual reality can quickly and efficiently convey abstract and complex knowledge, I decided to conduct yet another study, this time with the goal of teaching teachers about their students' exam anxiety. One critique we had received following our prior studies was that the subjects' knowledge was tested immediately upon completion of the experiment, and that we did not take into account that over time their knowledge might even out with the control groups who had received their knowledge through other means. We decided to test the subjects' knowledge twice before the experiment, and twice again after the experiment, at identical intervals for the test and control groups. We assessed whether the 3D IVR experience would influence the degree of empathy of teachers for students who suffers from exam anxiety. The experiment sample was made up of pre-service teachers.

The ninety subjects of the study were divided into three groups. The test group experienced a 3D IVR simulation that illustrated the cognitive aspects of exam anxiety (fig. 27); one control group watched a short television movie about exam anxiety; and another control group read testimonies of students who suffer from exam anxiety. We tested the participants' awareness of the subject four times: two weeks before the experiment, one week before the experiment, immediately following the experiment, and two weeks after it. At each stage, the subjects filled out a questionnaire about their awareness of exam anxiety, which was written especially for this study.[23]

Fig. 27. A 3D IVR simulation of exam anxiety

In this study, too, the group that experienced the IVR simulation demonstrated a significantly higher level of awareness than the control groups. What was interesting was that in the test conducted two weeks after the experiment, the experimental group's level of knowledge was even higher than immediately following the experiment. In order to make sure that there wasn't a mistake, we repeated the experiment with another group, this time not with pre-service teachers but with in-service teachers.[24] In this experiment, too, the experimental group demonstrated a higher level of awareness of exam anxiety, not only immediately after the experiment but two weeks later as well.

Improving Body Image

Encouraged by the success of these studies, we decided to try something more unusual, namely, to test whether technology can improve a kind of knowledge that is seemingly very difficult to improve. The literature shows that therapists who work with young people suffering from congenital cerebral palsy or early onset muscular dystrophy, have a hard time helping their patients improve their negative body image. We assumed that if we could significantly improve the body image of these young men and women, we could finally set aside the first tier of our experiments and safely claim that 3D IVR technology is capable at the very least of significantly enhancing learning processes in a short time. To this end, we constructed virtual 3D healthy bodies for every subject, which they could manipulate as they wished (fig. 28).[25] After that we assessed the influence of this experience on their body image. We examined the change in the body image of children in comparison with adolescents; those with congenital cerebral palsy in comparison with those with early onset muscular dystrophy; and girls in comparison with boys. In all of the experiments, we found that the experience of manipulating a healthy body in 3D IVR significantly improved their body image. This was a good example of the way in which 3D IVR technology is capable of improving comprehension of a concept that is very difficult to explain and to improve through conventional means.

Fig. 28. A 3D IVR simulation of a healthy body by a boy with cerebral palsy

Second Tier: Enhancement of the cognitive skills that are measured on standard IQ tests

After proving that advanced technologies can quickly and unequivocally enhance the comprehension of difficult concepts, we moved on to the second tier of the research design. We hypothesized that if we could use IVR technology to improve the cognitive skills that are measured on standard IQ tests, we could challenge Flynn's explanations and claim that environment alone cannot account for the accelerated improvement in intelligence, and that the advanced technologies at our disposal play a significant role in this phenomenon. Our method would be to compare test groups that use 3D IVR with control groups that use other technologies or learning process. Our hypothesis was that these control groups would not achieve the same improvements as the test groups, if at all. This would also indicate that technology as an “environment” by itself does not suffice, but that specific and more advanced technologies are in at work.

Enhancing Cognitive Flexibility

In the first stage, we assumed that if we could find a population whose scores on the various intelligence tests showed apparent deficiencies, despite years of attempting to improve their scores, and if we would succeed in improving these same cognitive skills, then we would be on the way to claiming, against Flynn, that it was not the “environment” in general but something else more specific that improved intelligence over the years. In effect, we set out to test the accuracy of Flynn’s statement that cognitive exercise, and that alone, is the important factor in the improvement of cognitive skills, and that a stimulating nurturing environment will help everyone realize their innate cognitive potential. One group of disabilities came to mind: children with different levels of hearing impairment, whether congenital or as a result of an injury or illness.

The literature indicated that these children attain lower scores in comparison with their normative peer group, on various IQ sub-tests. Therefore, in an unprecedented study, we set out to test whether practicing the rotation of three-dimensional objects in a virtual reality environment could influence the cognitive flexibility of hearing-impaired children.

The intervention with the experimental group included individual play with virtual three-dimensional objects, once a week over the course of three months, for about fifteen minutes each session. One control group played for the same amount of time and at the same intervals, with the same objects in two-dimensional computerized multimedia. We tested each of the groups before and after the intervention. With another control group of hearing children we assessed whether hearing-impaired children indeed attained lower results in cognitive flexibility in comparison with hearing children.

The test we used, before and after the 3D IVR simulation and the 2D multimedia intervention, was Torrance's circles sub-test,[26] which has been found to be reliable (Chronbach's α=.90). We used this test in order to assess whether the experience of rotating three-dimensional objects, which requires the ability to look at the object from different angles,[27] would influence the cognitive flexibility of the subjects. The test includes verbal and non-verbal tasks; we used only the non-verbal tasks.

The experiment results showed a significant improvement in the cognitive flexibility of the experimental group from before to after intervention.[28] The control group of hearing-impaired children did not show any improvement. Moreover, the hearing-impaired children produced lower test results than the hearing children in cognitive flexibility before the intervention, while after the virtual reality experience, they narrowed the gap significantly with the hearing children.

Enhancing Induction and Deduction Skills

Encouraged by these results, we looked for additional ways to corroborate our findings. Searching in the literature, we found that children with congenital hearing impairments tend to have lower achievements on the sub-test that assess inductive and deductive thinking.[29] We found that, despite special teaching methods that had been developed over the years, their scores in deductive and inductive thinking showed little or no improvement.[30] This was therefore a good opportunity to test the hypothesis that IVR technology can improve their scores on this sub-test within a very short time. We set out to test the achievements of children with a proven hearing disability before and after participating in a 3D IVR world that simulates abstract thought.[31]

For this experiment, we tested a group of eight- to eleven-year-old children in virtual worlds in which they could practice induction and deduction exercises. The sample included sixty children: an experimental group of 21 hearing-impaired children; a control group of 23 hearing-impaired children; and another control group of 16 hearing children. Hearing loss was determined at 88.62 decibels (dB) average hearing loss.

Both the experimental group and the control group of hearing-impaired children were tested before and after the experiment. The test we used was Cattell and Cattell's Structural Sequences sub-test,[32] which was developed in the 1960s and found to be reliable (α= .80) among children from different cultures. The goal was to test whether practicing rotation in a virtual environment (fig. 29) would influence their ability to generate inductive structural thought processes.

Fig. 29. A hearing-impaired child exercises rotations in 3D IVR.

The instructions for the tests were given to the hearing-impaired children out loud and in sign language, in order to ensure that all the children understood them. The hearing control group was tested on the same test, but only once.

As we assumed, this study also showed clear differences before the experiment in the formal induction scores between the hearing and hearing-impaired children, with the advantage to the hearing children.[33] After the experiment, the children in the experimental group who had used the IVR game improved their structural induction ability, closing the gap with the hearing control group. The control group of hearing-impaired children remained, on the other hand, with lower average scores, and the gap between them and the hearing group remained as it was.

While the study confirmed our hypothesis, the results were nonetheless surprising. In effect, the results of this experiment implied that cognitive skills could be improved at an incredible speed. These children practiced rotations in 3D IVR worlds just once a week for fifteen minutes, over the course of three months. In order to confirm that it was indeed the difference in technological environment that was the factor in the improvement, the control group of hearing-impaired children practiced, at the same intervals, spatial rotations two-dimensionally on flash cards. The findings showed that the experimental group, which practiced in a 3D IVR environment, improved their scores significantly more than the group that practiced with two-dimensional cards.

Improving Sequential Time Perception

These results further confirmed our suspicion that, indeed, not every kind of training brings about the same improvements in cognitive skills. However, we needed to conduct more studies in order to assert this claim with greater confidence. And so we searched for other skills to test.

We found that one of the cognitive skills in which hearing-impaired children have difficulty is the perception of time, particularly sequential time perception, or, the ability to perceive of events in a logical order. We prepared to examine how hearing-impaired children could improve their sequential time perception through a variety of modes of representation. In this study we tested the influence of 3D IVR representation (fig. 30), pictorial representation on cards, written representation, spoken representation, and sign-language representation, respectively, on sequential time perception among 69 hearing-impaired children aged four to ten.[34]

Fig. 30. Logical arrangement of the actions for preparation of a cake

In this study, we found that the 3D IVR representation and the signed representation brought about the most improved perception of sequential time. The lowest results were achieved with the written and pictorial representations.

Improving Time Connectives

In order to allay any doubt, we decided to confirm these results in another study with hearing and hearing-impaired children. For this purpose, we chose a cognitive disability that is common among both hearing and hearing-impaired children, namely, difficulty in identifying time connectives. These include the perception of time relations (for example, the expression "afterwards") and of cause and effect (such as the word "immediately"). The assumption was that if we succeeded using IVR technology, in improving both groups' perception of time connectives, we could safely say that it is VR technology that has a hand in the improvement.

In the experiment, we used a variety of modes of representation to test the different ways in which hearing-impaired children and hearing children comprehend time connectives. Here, too, we tested the influence of 3D IVR representation (fig. 31) in comparison with pictorial, written, spoken, and signed representations, among 69 hearing-impaired children and 65 hearing children aged four to ten.

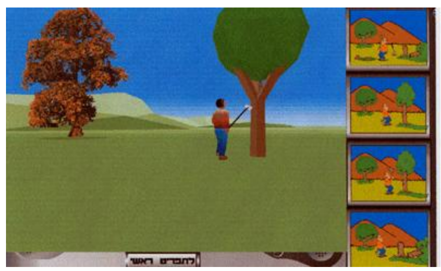

Fig. 31. Logical arrangement of the actions indicating the comprehension of cause and effect in chopping down a tree

We were pleased to see that in this study, too, the 3D IVR representation brought about the highest improvement in the perception of time connectives. The lowest results were, once again, in the written and pictorial representations.[35]

Improving Analogical Thinking

After we saw how hearing children improved their perception of time connectives, we decided to go even further and to test whether it was possible to improve another kind of basic thinking, which is known to be difficult, among a sample of normative children as well. In our literature review on the subject, we found that children from immigrant families of Ethiopian origin in Israel have trouble with analogical thinking. As a result, many of these children are diagnosed with learning disabilities and put in special-education frameworks. We thought that if we could improve the analogical thinking of these children in a short time using 3D IVR, we could be sure of our claim regarding Flynn's explanations. Moreover, if it turned out that these children did not improve this skill using other modes of representation that also enriched their environment with analogies, we could sum up this tier of studies and claim that it is advanced technology, and not the day-to-day nurturing environment, as stimulating as it might be, that has a hand in the improvement of intelligence.

For this study, we developed 3D IVR worlds entailing various analogies, and we tested whether it was possible to improve analogical thinking among preschool-aged Ethiopian-Israeli children. The sample included 56 Israeli children of Ethiopian origin, aged four to seven, whose parents had immigrated to Israel no more than ten years before their birth.

The research tool for measuring analogical thinking was developed by Tzuriel and Galinka[36] and was found to be a reliable test of various kinds of analogical thinking. Using this tool, we examined ten conceptual analogies and ten perceptual analogies. The IVR worlds we built in this intervention scheme were based on their test, known as The Conceptual and Perceptual Analogical Modifiability (CPAM) Test (fig. 32). The test was administered on three occasions: before the beginning of the intervention, immediately following the intervention, and three weeks after the intervention, in order to test the children's retention of the solution strategies.

Fig. 32. Children from immigrant families solving analogies

The intervention included two sessions of about fifteen minutes, in which the children practiced solving analogies. The test group practiced analogical solutions in a 3D IVR reality, while the control group practiced analogical solutions through a game with flash cards.

As we assumed, the children in the regular intervention using flash cards and objects received lower scores in analogical thinking, whereas they showed a significant improvement within a short time with the help of 3D IVR.[37]

Now we could say that it was possible, using 3D IVR, to improve the cognitive skills that are measured in standardized IQ tests. We could therefore claim, against Flynn's explanations, that it is the advanced technologies at our disposal that play a significant role in the enhancement that he himself identified in IQ, and that simple environmental factors cannot be those which accelerate this improvement. This is because the control groups that were exposed to other technologies or other stimulating environments did not achieve an improvement that came close to that achieved by the experimental groups that experienced the 3D IVR environments.

Third Tier: Improving IQ Scores even for those who lack genetic potential

Now we were ready to test the most important thing to help us confirm the inadequacy of Flynn's explanations, and to prove that something much more significant was at play in the accelerated improvement in intelligence that he himself identified. Until this point we had solid enough evidence to prove that a stimulating natural environment was not sufficient to create the accelerated improvement in IQ scores on various experiments, but that advanced technology such as immersive 3D IVR was capable of significantly improving a variety of cognitive skills, and with remarkable speed. We assumed, however, that many would claim that this technology was nothing more than another kind of stimulating environment. In truth, this is exactly how we would explain the results of our experiments; we attributed the improvement to the participants' level of immersion in the subjects on which they were being tested, to the level of interest they had in the new technology, and to the level of interactivity with the information that it enabled. We assumed, therefore, that there would be those who would claim that while we had proved that it was possible to accelerate the level of assimilation of various cognitive skills, ultimately virtual reality was just another kind of environment in which stimuli operate to improve test scores, and that this does not contradict Flynn's central claim that a stimulating environment is the cause for the improvement.

This kind of critique would leave the Flynn effect unchanged, as a phenomenon that basically says that if we only know how to provide the proper facilitators, the entire population will be capable of enhancing their IQ scores and realizing their innate genetic potential.

Therefore, we hypothesized that if we could improve IQ scores in a number of skills among populations that don't apparently have the genetic potential to do so, we could say with greater confidence that the Flynn effect is not the result only of stimuli-filled environments, but that it may be due to a very special kind of stimuli, whose essence, character, and full potential we have yet to understand. If that is the case, then the Flynn effect is only the tip of the iceberg of a more significant effect which we must identify and explain. Ultimately, if it turns out that people with congenital mental disabilities improve their scores on standardized IQ tests, then we will be able to begin to claim that Flynn's explanations are no longer sufficient, and we must find new explanations.

Improving Time Perception among Down Syndrome Teenagers

For this study, we sought out a population that is defined categorically as having a genetic mental disability. We found no better candidates than teenagers with Down Syndrome. The syndrome, which classified by John Langdon Down in 1866 and eventually named after him, stems from the trisomy of chromosome 21; i.e., a situation in which three, instead of two, copies of chromosome 21 are found in all or some of the cells in the body. People with Down Syndrome have mental retardation as well as unique physical features and other characteristic health problems.

Their main cognitive trait of Down Syndrome is a low IQ, ranging from 40 to 75. Depending on where they fall within this range, individuals with Down Syndrome are defined having a light, medium, or severe version of the syndrome. Their mental retardation means that their cognitive development is slower than normal and does not reach the standard level at any point in their life. Furthermore, they perceive of themselves as children and have little aspiration for independence, often remaining dependent on their family members throughout their lives. Almost all individuals with Down Syndrome learn to speak, and they can also be taught to read and write, though this takes longer than for the average person.

Searching carefully through the literature, we found that people with Down Syndrome have trouble employing cognitive strategies and comprehending abstract concepts, among them the concept of time. Since we were searching for a difficulty that we had already examined in one of the previous studies in relation to other physiological disabilities, we thought that if we would succeed in definitively improving the perception of sequential time among this population sample, we could strengthen the claim that Flynn's explanations are not sufficient to explain the effect that he identified.

For this experiment, we developed 3D IVR worlds in which the subjects could exercise sequential time using IVR technology. The sample included 87 boys and girls with a light to medium retardation, aged 9 to 21. They were divided into three groups: one experimental group, which practiced on 3D IVR time sequence scenarios; a control group, which practiced the same scenarios using two-dimensional pictures; and a control group that underwent no intervention.

To our satisfaction, we found that the subjects who used the 3D IVR representation improved their perception of sequential time more than the control groups.[38] Furthermore, the results testified that the success of those who used virtual reality required less mediation than the control groups.

Improving Concrete Thinking among Normative Children

After we proved that a stimulating day-to-day environment alone does not necessarily improve cognitive skills, we set out to examine whether it was also possible using technology to improve cognitive skills that are concrete. One should recall that Flynn found that only abstract cognitive skills have improved. My hypothesis was that if the subjects could significantly improve their perceptual analogical thinking, a kind of thinking that can be categorized as concrete, we could then assert that something is at play in the accelerated improvement in the various components of IQ, other than what Flynn claimed.

We devised a research scheme whose goal was to test whether it was possible to definitively and significantly improve concrete thinking skills. There were two things that we had to prove: first, that 3D IVR alone can significantly improve concrete thinking, as opposed to other technologies, such as 2D multimedia; and second, that even when conventional interventions are accompanied by the close and active guidance of the researcher, as in dynamic diagnosis, for example, the 3D IVR experimental groups still achieve higher and much more significant rates of improvement.

For this study, we built 3D IVR worlds containing complex problems in perceptual analogical thinking. Perceptual analogies can be defined as analogical problems in which knowledge about them is found within the problem itself, as opposed to conceptual analogies, which appear as symbols for which knowledge about their essence and the relations between them is dependent on the life experience of the subject and the knowledge he has accumulated up to this point. By complex problems, we mean problems that have a number of physical and concrete dimensions, such as color, size, amount, and location, whose complexity is manifested in a number of dimensions that act in conjunction that must be processed simultaneously in order to be solved.

David Tzuriel developed a dynamic test through which it would be possible to assess learning and the assimilation of perceptual analogies. According to the literature, the dynamic assessment process provides a better reflection of the subjects' capacity for cognitive change than regular (static) diagnosis. Tzuriel developed an array of wooden blocks of differing sizes and colors, which the subject places on a wooden surface in a variety of formations and amounts. This system helps assess analogical thinking in concrete perceptual analogies, through the solution of defined problems that are presented in rising level of difficulty, in which the subject must say how the solution of the analogy will look by laying the array of blocks on the board in different formations from different angles. The test is called Cognitive Modifiability Battery (CMB)[39] (sub-test AN).

I collaborated with Tzuriel to transpose his test into 3D IVR worlds that can be operated using an HMD, and into two-dimensional worlds that can be manipulated using regular mouse and keyboard on a computer screen (fig. 33).

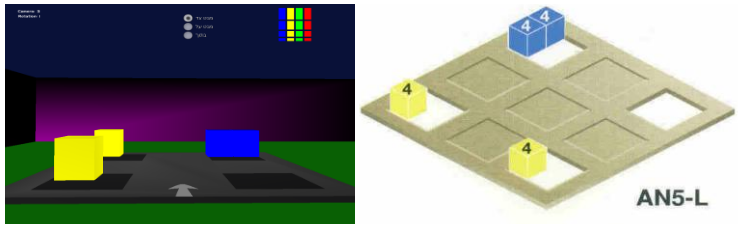

Fig. 33. CMB Test wood-block version and 3D IVR version

117 children, aged six to nine, in first and second grade, participated in the study. The sample was divided randomly into two control groups and an experimental group. Each group had a similar number of boys and girls. All of the groups underwent a dynamic assessment in perceptual analogical thinking, which included three stages: the diagnostic stage before learning, the learning stage, which included the mediation of an adult, and the diagnostic stage after learning. The first group worked in a 3D IVR environment; a second group worked in a two-dimensional multimedia environment (mouse-screen interface); and a third group worked in an environment with no computerized technology, but only with the help of a wood board and blocks, as was developed in the original test. The third control group was tested without computerized technological aids and without a learning stage.

We hypothesized that the children who went through the dynamic assessment in the 3D IVR environment would show greater cognitive change in perceptual analogical thinking than the children who experienced the dynamic assessment in the two-dimensional computer environment or in an environment without the computer. We further hypothesized that the unique characteristics of the 3D IVR environment in the framework of the dynamic assessment would help predict the children’s cognitive performance. This hypothesis was based on the fact that in the previous studies we had proven that it was possible to improve conceptual analogical thinking using 3D IVR environments. It was therefore reasonable to assume that we could improve perceptual analogical thinking with their help, in particular when the 3D IVR environments help the subjects make the analogies more concrete.

The findings in this experiment also supported the hypotheses in full. The greatest cognitive change happened among the group that was tested with perceptual analogies in a 3D IVR environment. Significant differences were found between the experimental group that used

IVR and the other two control groups.[40] Moreover, the significant advantage of the group that was tested in the 3D IVR environment was maintained in the solution of transfer problems in analogical thinking two weeks later, in an environment without computerized technology. It was found, therefore, that children who experienced dynamic assessment in a 3D IVR environment performed better in the solution of these problems than children who underwent dynamic assessment in a two-dimensional computer environment or in a non-computer environment.

Summary

Our work is not yet done, and the way is still long until the reliability of these preliminary results becomes clear. At the time of writing, we are continuing to design and conduct more studies with the goal of solidifying the results that show that it is possible to accelerate the enhancement of concrete thinking using 3D IVR technology. In the experiments, we test different populations and various abstract and concrete skills, under the assumption that we can increase cognitive change using 3D IVR technology and other advanced technologies such as Brain Computer Interface (BCI). We estimate that human society has passed the threshold before which these technologies were the property of the few, and that from now on they will be widespread and accessible. Therefore if our assessment, that something is at play in advanced, in particular 3D, technologies, proves reliable, then it will be possible to reopen the discussion that Flynn began and to try to understand the source of the Flynn effect from new perspectives.

Above all, we will be able to begin to claim that the effect that was measured in the last fifty years is but the opening shot of the cognitive change that the human species is bound to undergo during the twenty-first century. In this sense, the Flynn effect opens a window into a much more significant evolutionary process that is going to happen to human cognition in the coming century. One aspect of this process is the capacity of innovative future thinking; another part is self-awareness and collective awareness on a level that the human species has not yet known; and yet another small part of this process is the ability of

The Flynn effect is only the opening shot for the cognitive change that the human species is about to undergo in the 21st century.

cognition to improve in many familiar skills and in particular to master new and unfamiliar skills, all within a short time.

Since this book deals primarily with man's capacity at the beginning of the twenty-first century to expand his long-term future-thinking, with his ability to develop future-thinking, both individually and collectively, and his ability to jump to a higher level of self-cognition, I will make do in this summary with an expansion on this matter. Elsewhere I expanded on the subject of the cognitive abilities that our children will need to master in order to survive in future learning and work environments.[41] For this purposes I developed a taxonomy of future cognitive skills and defined them and their behavioral characteristics. In effect I expanded the taxonomy of cognitive skills that Blum et al. developed in the 1950s, adding a skill that is not learned in most of our training environments, from kindergarten through university, which I term "melioration." In recent years I have also dealt with the development of measurement indices for this and other skills.[42]

Back to the matter at hand, just as I suspected, the studies presented here indicate that the technologies we hold today, with their advanced interfaces, generate an accelerated enhancement effect in a large range of cognitive skills, an enhancement for which the environment alone cannot be responsible. Moreover, the studies show that the advanced technologies succeeded in improving not only abstract cognitive skills as the Flynn effect found, but also concrete cognitive skills.

It could be that something much more significant is happening under our radar.

If this is the case, then we have a great opportunity, at the beginning of the twenty-first century, to address anew many questions that Flynn's explanations managed to hide effectively under the rug for many years. For example, why did Flynn himself see fit to downplay the value of the effect that he identified? What was he afraid of when he stated that only the environment was responsible for the accelerated improvement in cognitive abilities? Why do many in the world still downplay the value of the Flynn effect? And why does the effect still strike many as illogical?

But the difficult questions have to do, most of all, with the future of the phenomenon. What is hiding behind it? What really motivates it? And in general, what is the future of human intelligence? Is the Flynn effect pointing in the right direction, if at all, or is it a byproduct of something else entirely?

I do not have the answers to these questions. It seems to me that much more time will pass before we witness a truly open discourse on this kind of issue in IQ scholarship. I believe the day will come when we will have the intellectual courage to examine these issues in depth and perhaps even to propose interesting ideas that will lead our children with greater confidence toward their future. For the time being I will make do with interim conclusions. If there are still those who doubt the assessment that human mental capacities are improving, whether through stimulus-filled environments or through advanced technology, I hope that at this point this doubt has all but dissipated.

My goal in this part of the book has been to illustrate that we should not fear dealing with the fact that man's cognitive abilities are improving. If we found an improvement on IQ tests, then certainly we can also claim that it will be possible to identify an improvement in man's future-thinking ability. In this sense, future-thinking is just one of many skills that man is improving. This improvement is occurring intrinsically through the exposure to large and complex databases, and through the great awareness of this complexity. But the improvement can also be conducted using structured learning processes, since cognitive skills can be improved with the sensible use of technology. These learning experiences can be individual processes on personal issues, or collective learning experiences with public, social, economic, and even cosmic implications.

In the next section of the book I will lay out the tools that we have at our disposal to enhance the individual's capacity of future-thinking on personal issues; and in the final section of the book I will lay out for the reader a paradigm with which it will be possible to confront one very difficult issue that faces us at the beginning of the twenty-first century, namely, the pension savings' paradigm.

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