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22. My research team's studies of virtual reality and multiuser virtual environments (MUVEs) are funded by the NSF, and our research on augmented reality is funded by the U.S. Department of Education. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of these funding agencies.

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10.1126/science.1167311

PERSPECTIVE

Technology and Informal Education: What Is Taught, What Is Learned

Patricia M. Greenfield

The informal learning environments of television, video games, and the Internet are producing learners with a new profile of cognitive skills. This profile features widespread and sophisticated development of visual-spatial skills, such as iconic representation and spatial visualization. A pressing social problem is the prevalence of violent video games, leading to desensitization, aggressive behavior, and gender inequity in opportunities to develop visual-spatial skills. Formal education must adapt to these changes, taking advantage of new strengths in visual-spatial intelligence and compensating for new weaknesses in higher-order cognitive processes: abstract vocabulary, mindfulness, reflection, inductive problem solving, critical thinking, and imagination. These develop through the use of an older technology, reading, which, along with audio media such as radio, also stimulates imagination. Informal education therefore requires a balanced media diet using each technology's specific strengths in order to develop a complete profile of cognitive skills.

Informal education—what goes on outside of the classroom—shapes our thought processes as they develop from early childhood. Media technologies are an extremely important part of informal learning environments. Media are also part of formal learning environments, the subject of other papers in this special issue on educational technology. The technologies composing the informal learning environment are generally intended for entertainment rather than education. However, they are important sources of cognitive socialization, often laying the foundation for knowledge acquisition in school.

In the midst of much press about the decreasing use of the print medium and failing schools, a countervailing trend may come as a surprise: the continuing global rise in IQ performance over more than 100 years. This rise, known as the Flynn effect, is concentrated in nonverbal IQ performance (mainly tested through visual tests) but has also occurred, albeit to a lesser extent, in verbal IQ (*1*–*5*). Rising IQ performance is attributable to multiple factors: increased levels of formal education, urbanization, societal complexity, improved nutrition, smaller family size, and technological development (*5*–*7*). These are interrelated rather than independent factors; they are part and parcel of the worldwide movement from smaller-scale, low-tech communities with subsistence economies toward larger-scale, high-tech societies with commercial economies (*8*). Which specific factor is most important in raising IQ performance at a given time and place depends on the locus of social change occurring then and there (*6*, *8*). Increasing levels of formal education and urbanization were particularly important in the United States and Europe in the first half of the 20th century (*9*, *10*). More recently, technological change may have taken the dominant role.

The changing balance of media technologies has led to losses as well as gains. For example, as verbal IQ has risen, verbal SATs have fallen. Paradoxically, omnipresent television may be responsible for the spread of the basic vocabulary (*11*) that drives verbal IQ scores, while simultaneously the decline in recreational reading may have led to the loss of the more abstract vocabulary driving verbal SAT scores (*6*, *12*, *13*).

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Evidence for the Flynn Effect

Among several kinds of test data from 20 industrialized countries, Flynn compared records of British people tested in 1942 and 1992 on Raven Progressive Matrices (Fig. 1 shows a sample item). Between 1942 and 1992, average performance increased for all age groups (Fig. 2) (*4*). Note that the oldest members of the first cohort tested grew up in the last two decades of the 19th century, extending the baseline back that far.

The new organization of Flynn's data in Fig. 2 reveals another important point: Not only is performance on the matrices better in the later cohort but cognitive aging is also reduced—witness an almost flat slope of performance across the age groups tested in 1992. This slope contrasts with the age-related decline seen in the groups tested in 1942.

Male military recruits supplied most of Flynn's data, skewing samples toward a relatively low socioeconomic population and excluding women. A University of California, Los Angeles, team (*5*) later demonstrated the Flynn effect in rural

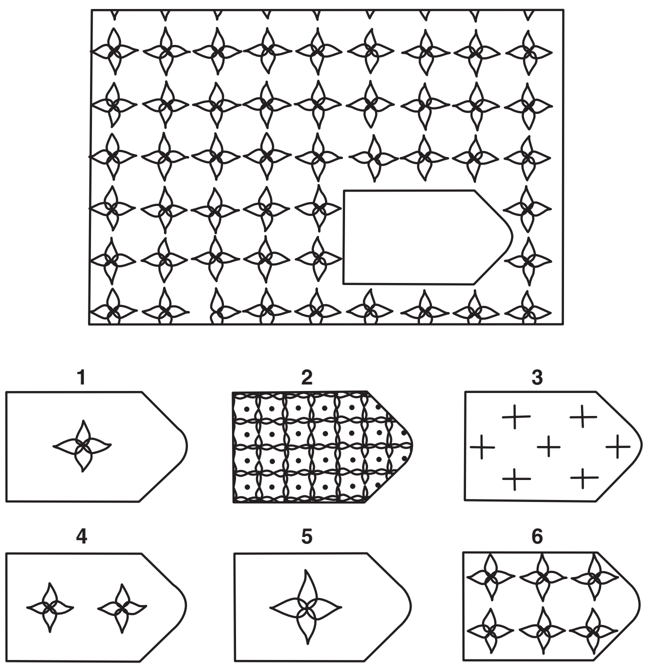

Fig. 1. A simple item from Raven Standard Progressive Matrices. From the six inserts at the bottom of the figure, the participant selects the one that logically fits in the matrix above. [Figure A5 of the Raven Standard Progressive Matrices, by J. C. Raven. Copyright 1938, 1976 by J. C. Raven Ltd. Reprinted with permission]

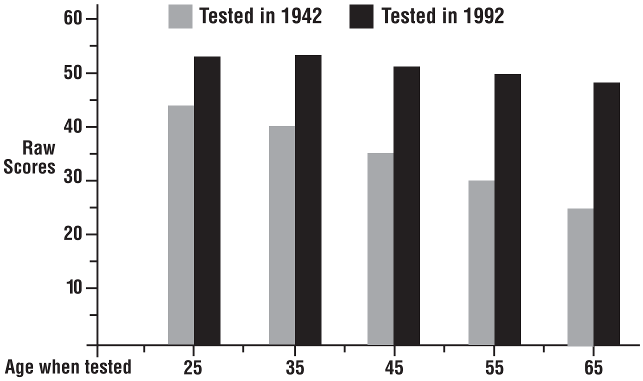

Fig. 2. Comparing performance on Raven Progressive Matrices in British people of different ages tested in 1942 and 1992 (*4*). Each bar represents 50th-percentile performance for a particular age group tested in a particular year. It is necessary to equate for age because of the influence of cognitive aging, seen in the decline of raw scores for pairs of bars with increasing age. However, decline was less pronounced in 1992 than in 1942.

Kenya, testing younger people, both boys and girls.

Technology and Visual Intelligence

Raven Progressive Matrices, like most so-called nonverbal IQ tests, provide a measure of visual intelligence, a concept that includes but is broader than Gardner's "spatial intelligence" (*14*). From the second half of the 20th century to the present time in the United States, highly popular forms of technology, such as television (currently with 99% penetration) (*15*) and, more recently, video games (currently with 97% penetration) (*16*), have taken a major role in developing visual intelligence on a mass scale, producing learners with capabilities that match the visual demands of modern science and technology.

The understanding of pictures or icons develops at an earlier age than the ability to read words (*17*). Building on this ontogenetic primacy, television, film, and video games augment basic visual literacy skills such as iconic representation (*18*), spatial orientation (*19*, *20*), spatial visualization (*20–26*), and other visual skills (*27*) that are important in the virtual world of computers (*28*, *29*). This cognitive socialization produces learners who are particularly well suited to take advantage of media-rich environments for formal education (*30*, *31*) and possess the visual literacy skills used in many modern professions.

Iterative and reciprocal processes are undoubtedly involved: Designers raised on visual media themselves create ever-more-sophisticated visual environments, in turn augmenting the visual skills of the next generation of young consumers. Take divided attention: keeping track of multiple events at different locations on a screen. Correlational and experimental data collected a decade apart show that divided attention is enhanced by playing action video games (*32*, *33*). However, the game *Medal of Honor*, used as an experimental treatment in the more recent study, was much more visually sophisticated and had broader effects on visual attention than did *Robotron*, used as an experimental treatment a decade earlier [see also (*34–36*)].

Technology and Multitasking: Benefits and Costs

Divided attention is the precursor and prerequisite for multitasking, defined as carrying out more than one task simultaneously. So do video games promote skill in multitasking? Research provides an affirmative answer. Kearney measured multitasking with *SynWork*, which simulates elements of work-based activities and measures composite performance on four tasks carried out simultaneously. Playing 2 hours of a shooting game called *Counter-Strike* improved multitasking scores significantly over those of a no-play control group (*37*). What we do not know from this study is whether each of the four tasks could have been performed better or processed more deeply if done alone, rather than in a multitasking environment. This is an important question, given the all-pervasiveness of multitasking in today's technological environment, especially for youth (*38*, *39*).

An experimental study by Foerde and colleagues answers this question (*40*). They developed a weather prediction task in which one condition used a distractor task (multitasking condition), whereas the other did not (single-task condition). In both conditions, participants learned to use cues equally well to predict the weather; however, they often were unaware of what cues they had used when they were in the dual-task distractor condition. Under multitasking conditions, cognitive processing was less mindful and more automatic.

Another study of the cognitive effects of multitasking used CNN Headline News to simulate a socially realistic and important cognitive task; understanding the news. While news anchors present their stories as talking heads on Headline News, weather forecast icons, sports scores, stock quotes, and textually delivered news crawls all appear at the bottom of the screen. To process these simultaneous stimuli requires multitasking. Such formats are very popular with younger viewers (ages 18 to 34), whereas older viewers (over 55) dislike them most (*41*, *42*). Nonetheless, the distracting information exacts a cognitive cost, even from the younger generation who have had more experience with multitasking. A controlled experiment showed that college students recalled significantly fewer facts from four main news stories in CNN's visually complex environment than from the same stories presented in a visually simple format, with the news anchor alone on the screen and the news crawls etc. edited out (*41*).

Implications for Education and Training

Internet multitasking also has costs for classroom learning. What is the effect on learning if college students use their laptops to access the Internet during a classroom lecture? This was tested in a communication studies class where students were generally encouraged to use their laptops during lectures, in order to explore lecture topics in greater detail on the Internet and in library databases (*43*). Half of the students were allowed to keep their laptops open, while the other half (randomly assigned) had to close their laptops. Students in the closed laptop condition recalled significantly more material in a surprise quiz after class than did students in the open laptop condition. Although these results may be obvious, many universities appear to be unaware of the learning decrement produced by multitasking when they wire classrooms with the intention of improving learning.

Laparoscopic surgery provides an example in which visual skills developed by video games have implications for training. Surgeons recognize that laparoscopy has changed the required skill profile of surgeons and their training needs (*44*). In laparoscopic surgery, a small incision is made, and a viewing tube with a small camera on the eyepiece is inserted through it. The surgeon examines internal organs on a video monitor connected to the tube and can also use the viewing tube to guide actual surgical procedures. Navigating through and operating in a three-dimensional space represented on a two-dimensional screen with minimal tactile feedback constitute basic parallels between laparoscopy and action video games. A study of the relation between video game skill and success in training for laparoscopic surgery yielded positive results (*44*): Action video game skill (as demonstrated in the laboratory) and past video game experience (assessed through self-report) predicted laparoscopic skills; in contrast, neither laparoscopic experience in the operating room nor years of training significantly predicted laparoscopic skill. The best game players (the top third) made 47% fewer errors and performed 39% faster in the laparoscopy tasks than the worst players (the bottom third). These results indicate the value of video game play as informal educational background for specific training in laparoscopic surgery, a finding that is applicable to other lines of work (such as piloting a plane) whose skill profiles overlap with those required by action video games.

Violent Games: Are the Costs Worth the Benefits?

Up to now, the discussion has ignored content and centered on the cognitive effects of video game forms, forms that can be used to present any content. However, game content is crucial to psychosocial effects, such as the effects of violent screen activity. Indeed, more than 85% of games contain violence (*45*). Research shows that playing violent video games produces aggressive behavior, aggressive affect, aggressive cognition, physiological arousal, desensitization to real-life violence, and a decrease in prosocial behavior (*45*, *46*). The cost/benefit tradeoff of violent games is epitomized by the finding that Chinese children who play video games extensively not only have higher nonverbal IQs but also are more aggressive (*47*).

Fostering Scientific Thinking Through Informal Learning

Although visual literacy is a tool in scientific thinking and can lead to discoveries (such as Hack's discovery of a new jaw muscle when he altered the normal visual perspective used by dentists for dissection) (*6*), scientific thinking goes beyond the techniques provided by visual literacy, highlighting the importance of a number of other qualities: reflection, inductive analysis, critical thinking, mindful thought, and imagination. We start with reflection and inductive analysis.

By their very nature as a real-time medium, action video games penalize the player who stops to reflect. Indeed, no real-time medium—including film, television, and radio—permits time to reflect (*28*). The one communication technology that does provide time to reflect is the written word. Indeed, we have known for more than 40 years that there is an association between reading skill and reflection: Starting in first grade, better readers are also more reflective than less skilled readers (*48*). And reflection (contrasted with impulsivity) is associated with inductive problem-solving competence in children as young as first grade (*49*). Whereas reading is associated with reflection, television is associated with impulsivity. Over a 6-week period, an experimental reduction in television watching in a group of 6-year-olds decreased intellectual impulsivity, increased reflection, and increased time spent reading (*50*).

Reading is also key to the development of critical thinking. The amount of out-of-class reading done during the college years is a statistically significant predictor of critical thinking skills (*51*). One reason for this may be that books are perceived as a "hard" medium, requiring mental effort (*52*).

Imagination is important in scientific discovery as well as in the creation of literature and art. Here there is evidence that visual technology inhibits imaginative response. In controlled experimental studies, the audiovisual (television) presentation of stories, as compared with audio or print presentation of the same stories, led to better story recall and inferences (*53*, *54*). However, as compared with radio or print, the visual element in television also led to weaker imaginative responses, defined as the creation of original elements not found in the preceding stimuli (*53*–*55*).

Conclusions

Schools often rely on older media such as print and lectures to communicate with learners who increasingly lack the cognitive socialization—the informal education—that would enable them to process these media with maximum efficiency. Not only that, but schools rely almost entirely on the print medium to test that knowledge. Indeed, as science and technology have become increasingly visual in their intrinsic nature, there may be a mismatch between the structure of the knowledge and the structure of the print and oral language media traditionally used to both impart and test that knowledge.

However, the preceding makes it clear that no one medium can do everything. Every medium has its strengths and weaknesses; every medium develops some cognitive skills at the expense of others (*28*). Although the visual capabilities of television, video games, and the Internet may develop impressive visual intelligence, the cost seems to be deep processing: mindful knowledge acquisition, inductive analysis, critical thinking, imagination, and reflection. It is difficult for schools to teach reflective habits of mind to children whose informal education and cognitive socialization have not prepared them for this kind of learning and thinking. Yet society needs reflection, analysis, critical thinking, mindfulness, and imagination more than ever. The developing human mind still needs a balanced media diet (*28*), one that is not only virtual, but also allows ample time for the reading and auditory media experiences that lead to these important qualities of mind.

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56. Many thanks to K. Subrahmanyam and B. Tynes for valuable and timely input on the first draft.

10.1126/science.1167190