What is spatial ability?

Spatial ability is the capacity to understand and remember the spatial relations among objects. This ability can be viewed as a unique type of intelligence distinguishable from other forms of intelligence, such as verbal ability, reasoning ability, and memory skills. Spatial ability is not a monolithic and static trait, but made up of numerous subskills, which are interrelated among each other and develop throughout your life.

Why is spatial ability important?

Visual-spatial skills are of great importance for success in solving many tasks in everyday life. For instance, using a map to guide you through an unfamiliar city, merging into high-speed traffic, and orienting yourself in your environment (as when you are learning your way around a new school building) are all activities that involve spatial ability. Other examples of tasks requiring visual-spatial ability include packing (as when you must decide if a certain box is large enough for the objects you want to put into it) and using mirror images (as when you are combing your hair while looking into a mirror).

Spatial ability is also important for success in many fields of study. Mathematics, natural sciences, engineering, economic forecasting, meteorology and architecture all involve the use of spatial skills: For instance, an astronomer must visualize the structure of a solar system and the motions of the objects in it. An engineer visualizes the interactions of the parts of a machine. Radiologists must be able to interpret the image on a medical X-ray. Chemical sum formulas can be viewed as abstract models of molecules with most of the spatial information deleted; spatial skills are important in restoring that information when more detailed mental models of the molecules are needed. More formal evidence on the importance of spatial ability in math and science education has been compiled by many researchers, including Humphreys, Lubinski, Shea, Wai, and Webb. Some of their publications are cited in the *Readings* section below.

Traditionally, critical features of spatial ability in science education have been the skills required to construct efficient mental models of objects from verbal descriptions in textbooks or instruction. In some fields, textbooks and instruction materials have been developed that are explicitly designed to use spatial skills as a key to mastering the subject matter. Several such books are listed in the *Readings* section at the end of this document.

While the development of such materials continues to be an important concern, recent technological developments have added further emphases to the issue.

Visual-spatial ability is becoming increasingly important with the development and proliferation of new technologies such as imaging, computer graphics, data visualization, and supercomputing. Highly demanding spatial tasks include the construction of mental representations of object configuration from images on several screens representing different perspectives, as in some fields of surgery.

In other fields, powerful computer graphic technologies are being used to create complex visual images of processes that occur in the natural world. These techniques are used to depict the intricate workings of the immune system, the complex meteorological interactions that occur in a developing thunderstorm, hurricane, or tornado, and the relations of atoms and molecules in chemistry.

Despite their importance in so many fields, in science education, spatial skills rarely work in isolation from other abilities, such as logical reasoning, efficient memory retrieval, and verbal skills, and deficits in one area can often be compensated by excellence in others. An important type of exceptional talent in math and science, however, is the ability to easily switch form one efficient mode of representation to another (e. g., from a conceptual to a spatial mode and vice versa).

THE STB AND EDUCATIONAL PLANNING

CTY introduced The Spatial Test Battery (STB) in 1995 to aid in the identification of scientific and mathematical talent. The types of items included on the STB have been used in numerous studies in the past to measure the construct of general spatial ability, various subskills, and to predict a variety of educational and occupational criteria. Results of research conducted at CTY indicate that spatial ability is predictive of success in math and science courses offered by CTY.

Since 1996, thousands of students who would not have otherwise qualified for CTY courses with SAT, ACT or SCAT scores alone, have been able to establish eligibility by combining their STB scores with their SAT, ACT or SCAT scores. Follow-up studies have shown that these students have performed as well as students qualifying with SAT scores alone. In 2011, CTY established eligibility criteria so that students may qualify for math and science courses using solely their STB score. Many students who have SAT, ACT or SCAT scores that are well above the CTY cutoff for program eligibility also elect to take the STB simply to know the level of their spatial abilities. Many are surprised to find that they have a special talent in this area.

Educational Planning

Your STB scores can provide you with valuable information that you can use in planning your education. While interpreting your scores, you should keep two basic concepts in mind. First, spatial ability is a relatively enduring trait, but the scores are momentary snapshots of it and may be affected by other factors as well (such as fatigue, illness, disturbances and distractions during the testing, inefficient test taking strategies, etc.). Second, despite being relatively stable over time, spatial ability is also subject to middle- and long-term changes, especially through practice, training, maturation, and influences affecting health. These two points are discussed in more detail in the two following sections.

Ideally, your education should be matched to your abilities and interests so that you can be appropriately challenged and maximally motivated to learn. Knowing as much as possible about your strengths and interests in all areas is critical. You will probably have numerous opportunities to get feedback about your verbal and mathematical abilities, but spatial abilities are not often measured. Since you have taken the STB, you will have this valuable information to combine with all you know about yourself. Students who score well on the STB (above 500) may wish to consider careers that place a high emphasis on spatial ability. Careful educational planning should be an ongoing process with both short- and long-term goals being set. You and your parents should establish a close working relationship and dialogue with your teachers and counselors as soon as possible. With good information and careful planning, you, your parents, and your school can ensure that you obtain an outstanding education.

CTY's Diagnostic and Counseling Center (DCC) offers fee-based educational planning services and in-depth testing for students. Most testing is performed on-site in Baltimore, Maryland; however, some educational planning can be conducted over the telephone. The DCC also offers an Academic and Career Guidance service for highly able students that is available by mail. Visit the DCC website at *cty.jhu.edu/dcc/index.html* for more information.

Can Spatial Ability be further Developed?

It is important to note that the skills that make up spatial ability are the results of long learning and training processes (beyond developmental gains and other factors). The level of spatial performance someone is capable of may change over time. You are likely to gain in performance through practice, training, and learning, but you may also lose in standing relative to others if they acquire more experience that supports their performance or make more progress in their intellectual development. So, if you are interested in getting a long-time perspective on your spatial skills, it is advisable to have the testing repeated from time to time. This, of course, applies the more the younger you are when you take a spatial test.

If you wish to improve the level of performance you have reached, an important consideration is the possibility to enhance it through practice, training, and leaning. Modern computer software, among other things, offers many options to practice spatial skills. Even computer games that were not developed with the explicit intent to provide such training, such as Block Out and several versions of Tetris, have been found to contribute to enhancing spatial skills. On a more technical and advanced level, training materials have been provided in books and other publications, some of which are listed in the bibliography of this guide. If you decide to engage in such training, it is important to consider a broad range of tasks and not to focus on a few isolated functions exclusively. Research has shown that significant gains can be made on isolated tasks relatively quickly, but that extended effort is required to achieve substantial, broad, and lasting improvements in performance.

Two references in the *Readings* list are meant to give you an impression of the breadth of what is subsumed under "spatial ability:" The edition by Eliot and Smith provides a good overview on the variety of existing types of spatial

tasks; the book edited by Gilbert provides interesting examples from the study of the sciences. These latter publications, however, are scientific documentations and were not written for training purposes.

Formal training, however, is not the only way to develop spatial skills. You may pursue a large range of options if you are interested in understanding more about your spatial ability and developing this important talent. You should carefully consider each option listed below and match the options to your age, interests, and abilities.

- Find out more about spatial ability by reading some of the articles and books on the *Reading*s list in this guide.

- Study some of the materials provided in the publications by Baartmans & Sorby, Eliot & Smith, Nelsen, Nelsen & Watkins, and Sorby & others listed in the bibliography.

- The study of geometry has also been found to improve spatial visualization skills. This finding is not surprising but important to note, because geometry is often neglected in school curricula and educational practice. Geometry textbooks, if studied carefully, are likely to offer more benefits than just the accumulation of formal knowledge.

- Play computer games that involve manipulation of moving objects. The article by Martín-Gutiérrez and others cited in the *Readings* section mentions some of the promising recent software used for training spatial skills.

- Enroll in additional coursework in school in subject areas (like math, science, art, mechanics, or computers) where you could employ and develop your spatial talents.

- Take advantage of programs outside of school that could help you pursue visual-spatial interests. For example, you may want to join a photography or chess club or consider taking a course in computer graphics, architecture, or astronomy.

- Pursue hobbies or activities that can help to improve your visual-spatial skills, such as Lego building (including computer versions), photography, doing jigsaw puzzles, playing chess, drawing, geography, studying origami or practicing visual memory games.

- Explore careers which employ your spatial skills such as mathematics, engineering, physics, chemistry, architecture, medical technology, radiology, surgery, meteorology, astrophysics, graphic design, the computer or movie industry (specializing in computer animation and special effects).

- Consider finding a mentor or performing an internship in one of the fields mentioned above with an emphasis on developing your spatial skills.

Further Readings on Visual-Spatial Ability

Baartmans, B.G., & Sorby, S.A. (1996). *Introduction to 3-D spatial visualization.* Englewood Cliffs, New Jersey: Prentice Hall. (Contains exercises to improve spatial ability). ISBN 0-13-191610-6

Barke, H.D., et al. (2009). Misconceptions in chemistry. Addressing perceptions in chemical education. Heidelberg (Germany), New York: Springer-Verlag. ISBN 978-3-54070988-6.

Carroll, J. B. (1993). *Human cognitive abilities* (chapter 8: Abilities in the domain of visual perception). New York: Cambridge University Press. ISBN 0-521-3871-4

Eliot, J., & Smith, I.M. (1983). *An international directory of spatial tests.* Windsor, Great Britain: NFER-Nelson Publishing. ISBN 0-7005-0517-2

Gilbert, J. K. (Ed.). (2005). *Visualization in science education.* Dordrecht, The Netherlands: Springer-Verlag. (A collection of scholarly articles on the importance of spatial visualization in science education with instructive examples). ISBN 1-4020-3612-4

Humphreys, L.G., & Lubinski, D. (1998). *Assessing spatial visualization. An underappreciated ability for many school and work settings.* In C. P. Benbow & D. Lubinski (Eds.), Intellectual talent. Baltimore: Johns Hopkins University Press. ISBN 0-8018-5302-8

Humphreys, L. G., et al. (1993). *Utility of predicting group membership and the role of spatial visualization in becoming an engineer, physical scientist, or artist.* Journal of Applied Psychology, 78, pp. 250-261.

Lohman, D. F., et al. (1987). *Dimensions and components of individual differences in spatial abilities.* In S. H. Irvine & S. E. Newstead (Eds.), Intelligence and cognition (pp. 253-312). Dordrecht, The Netherlands: Martinus Nijhoff. ISBN 9-02473-523-8

Martín-Gutiérrez, J., et al. (2009). *Do video games improve spatial abilities of engineering students?* International Journal of Engineering Education, 25, pp. 1194-1204.

Nelsen, R.B. (1993). *Proofs without words: Exercises in visual thinking.* Washington, D.C.: The Mathematical Association of America. (A fascinating collection of examples of how spatial approaches can be used to solve a variety of mathematical problems). ISBN 0-88385-700-6

Nelsen, R.B., & Watkins, W. (2001). *Proofs without words II.* Washington, D. C.: Mathematical Association of America. (See remarks on previous reference). ISBN 0-88385-700-6

Nelsen, R.B., et al. (2006). *Math made visual.* Washington, D. C.: Mathematical Association of America. ISBN 0-88385-746-4

Shea, D.L., et al. (2001). *Importance of assessing spatial ability in intellectually talented young adolescents: A 20-year longitudinal study.* Journal of Educational Psychology, 93, pp. 604-614.

Sobanski, J. (2002). *Visual math. See how math makes sense.* New York: Learning Express (An introduction to fundamental mathematical concepts based on a visual approach). ISBN 1-576855-404-3

Sorby, S.A., et al. (1998). *3-D visualization for engineering graphics.* Upper Saddle River, NJ: Prentice Hall. ISBN 0-13191-602-5.

Souvingier, E. (2000). *Förderung räumlicher Fähigkeiten.* New York: Waxmann. (An overview of research on enhancing spatial ability in an educational context; in German). ISBN 3-89325-897-3

Stumpf, H., & Eliot, J. (1999). *A structural analysis of visual-spatial ability in academically talented students.* Learning and Individual Differences, 11, 137-151.

Stumpf, H., & Haldimann, M. (1997). *Spatial ability and academic success of sixth grade students at international schools.* School Psychology International, 18, 245-259.

Wai, J., et al. (2009). *Spatial ability for STEM domains.* Journal of Educational Psychology, 101, 817-835.

Webb, R., et al. (2007). *Spatial ability: A neglected dimension in talent searches for intellectually precocious youth.* Journal of Educational Psychology, 99, 397-420.

West, T.G. (1997). *In the mind's eye: Visual thinkers, gifted people with learning difficulties, computer images, and the ironies of creativity* (2nd ed.). Buffalo, NY: Prometheus Books. ISBN 0-88385-746-4

Exploring Career Options: Architecture, Landscape Architecture, And Exhibit Design

Excerpts from an interview by Carol Blackburn first appearing in *Imagine*, Vol. 2, No.4

In this interview, three professionals talk about their work together in a Seattle-based specialized design firm called the Portico Group. ***Chuck Mayes****, an architect and exhibit designer, is one of the founders of The Portico Group.* ***Dennis Meyer****, a landscape architect and exhibit designer, has been at Portico for eight years.* ***Elizabeth Bumpas****, an architect intern and interpretive planner, began working at Portico two years ago, immediately after completing her Master of Architecture degree.*

What does the Portico Group do?

Chuck: Our firm does unusual work. We've a diverse group of about 25 creative people who have gathered together to practice architecture, landscape architecture, exhibit design, and interpretive planning.

The other aspect of what we do as exhibit designers and interpretive planners is to tell stories. We try to use design and storytelling to make informal educational experiences more meaningful.

Storytelling seems like an unusual activity for an architect. Could you explain what you mean?

Chuck: For example, at the Woodland Park Zoo in Seattle, we designed a Tropical Rain Forest Complex, which depicts plants and animals in their natural habitats. The exhibit path leads visitors through a sequence of tropical habitats, from an "edge of civilization" biosphere through a secondary forest succession to a primary rainforest. Within the rainforest, the exhibit path moves from the forest floor up through the middle zones of the canopy and eventually out to the top of the vegetation canopy, revealing the complexity of the web of life that is the undisturbed forest.

Each habitat—and even each vertical zone within it—has its own characteristic animal and plant inhabitants, with their stories of life within that world. And by exhibiting the sequence of habitats, we can also show how modern development has affected the native biosphere. The designer and the storyteller in us worked together to create a spectrum of homes for animals and plants that also communicates something about their interrelationships.

Could you describe a project you've especially enjoyed doing?

Chuck: We've recently completed a very exciting project at Oregon State University Hatfield Marine Center. The Center has some amazing scientists doing fascinating work. One is using chaos theory to model the learning behavior of sea slugs; another is tracking whales at sea using radio transmitters and satellite uplinks. A third studies life in geothermal vents on the ocean floor, and others are using remote sensing to map environmental changes within the Northwest forests. Our design goal was to help the uninitiated visitor appreciate the complex scientific research being conducted at the Center.

Elizabeth: And the design we created for the Center reflected those people and their interests both explicitly, through interactive exhibits within the Center, and subtly, through design elements—a series of spiral patterns that create a recurrent visual link. The entry drive is laid out on the line of an immense spiral, bringing the visitor to the Center building with its entry courtyard, both of which are also abstracted spiral forms. The spiral evokes images of two realms that are important in the Center's research: nature (a snail's shell) and abstract thought (fractal geometry).

Dennis: What was wonderful about that project was that it gave us the opportunity to take the realm of pure ideas and translate it into three-dimensional site and building designs. The spiral design element reappeared visually and spatially in many manifestations: in paving patterns, in building entryways, even in tree positioning—we laid out the plantings using a chaos theory formula. Its subtle, unifying presence throughout the site is intended to remind visitors that scientists—and the scientist in each of us—are always seeking to find underlying patterns to structure our experience and understand our world.

Do you have any advice for young people on their own path? Any observations to make with the wisdom of hindsight?

Dennis: It's important to be flexible. When you follow your intuition and see where it leads, various career paths or interests become evident.

A final hint: Your skills and abilities shine more when you're fascinated. If you can find something that really interests you, you'll not only *be* happier, but you'll do better, more creative work—and it won't feel like work.