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What the Shadow Knows: Assessing Aspects of Practical Intelligence with Aurora's *Toy Shadows* (in press)

for the volume *Talent Development and Excellence*, Heidrun Stoeger, Abdullah Aljughaiman, and Bettina Harder (eds)

Abstract

The proper identification and education of gifted children has become an increasingly powerful imperative as countries consider how best to meet new problems in a complex and fast-changing world. To address a dearth of innovative assessments for intelligence, the Aurora Battery was developed, based on Robert J. Sternberg's theory of successful intelligence. Containing subtests for the assessment of creative and practical abilities, along with analytical, Aurora has drawn international interest as a more wide-reaching measure of intelligence. In this chapter, we focus on one of Aurora's tests for practical intelligence in the figural domain, ***Toy Shadows***, which was designed as a measure of individuals' implicit knowledge concerning the interpretation of shadows. Comparative analyses of ***Toy Shadows***' performance in three countries with three distinct samples, looking at group performance, item analysis, and employing confirmatory factor analysis, show that this assessment draws upon a single latent factor across cultures. These results provide some measure of encouragement toward further validation of the assessment, and support Aurora's promise as a battery that may provide much needed new views on intelligence and the identification of gifted students.

1 Introduction

The search for new assessments for the identification of the gifted implies an active interest in just that—a look at something new, something that has not been looked at before, or something that has been overlooked or needs consideration in a new light. This may explain in part the international interest that has been expressed in the Aurora Project over the last five years, from countries such as Greece, India, Israel, the Netherlands, Mexico, Portugal, Saudi Arabia, Singapore, and Slovakia, among others. Aurora is the development of an assessment for intelligence (designed for ages 9-12) based on Robert J. Sternberg's theory of successful intelligence. As such, it introduces some unconventional types of assessments.

According to Sternberg's theory of successful intelligence (Sternberg, 1999, 2005), three types of abilities, selected and balanced as needed, contribute equally to the successful achievement of goals. These are: analytical intelligence, creative intelligence and practical intelligence. Analytical intelligence is exerted typically in situations that require evaluation, judgment, logic, comparing and contrasting. Creative intelligence comes into play when one is asked to generate new things or ideas—to imagine, invent, design. It also plays an important role, according to Sternberg, in an individual's ability to cope with relative novelty. And finally, practical intelligence is called to action when solving problems that come up in situations of everyday life, such as those encountered at home or at work or in non-academic aspects of school. The paper and pencil component of the battery contains subtests that address each of the three types of intelligence, within the domains of words, numbers and images.

In this chapter, we will focus on one of the subtests for practical intelligence in Aurora's paper and pencil group test battery, ***Toy Shadows***, an assessment that comes at practical intelligence in a novel way. We will discuss its theoretical bases, compare its performance in the US, Greece, and Saudi Arabia, and consider what it can tell us about gifted individuals that may contribute to their further intellectual development. We propose that the ***Toy Shadows*** assessment is an appropriate and useful measure of a particular aspect of practical intelligence, and one that, moreover, behaves consistently across cultures.

2 The nature of practical intelligence and the complexities of its assessment

As Sternberg and others have argued, practical abilities are as important to the full execution of one's intelligence as analytical and creative abilities. Whatever one's strengths, practical abilities help them come to fruition in the world. The scientific or mathematical genius has to come up with new ideas, then communicate his or her findings to the larger community. The creative genius has to evaluate his or her ideas, then know how to sell their creations (often unconventional) so that they can be appreciated and used by others. Our analytical, creative, and practical abilities are intertwined in our work and in our lives. Thus, recognizing and assessing for all three of these abilities, then addressing them in the classroom should be part of any educational program that strives to nurture children's full potential (Mandelman & Grigorenko, in press; Sternberg, 1999, 2010; Sternberg et al., 2000; Sternberg & Grigorenko, 2007).

Sternberg's view of practical intelligence may be decomposed into three basic aspects for the purposes of assessment: the ability to acquire knowledge and understanding without explicit instruction (tacit knowledge); the ability to appropriately and effectively apply knowledge (tacit knowledge, or knowledge that may have been learned explicitly in school or at home) to everyday or real life situations; and the ability to successfully integrate oneself socially, by exercising social skills and, further, to exert one's social skills in a way that can effect change, such as by leading or persuading. The core factor here is the individual's successful interactions and operation within the external world, i.e. problem-solving or goal attainment in the context of life.

The defining feature of practical intelligence is that its execution is context-specific; that is, it is very difficult to separate practical problem-solving from the context in which it unfolds (Dixon, 1994; Sternberg, et al., 2000; Wertsch & Kanner, 1994). Hence, the difficulty (almost contradictory nature) of developing assessments for practical intelligence is inherent, since its particular defining quality is that it is ostensibly practiced in the real world (and not only in test-taking contexts or environments, though certainly it is also practiced there, to some extent).

However, if we are convinced that practical intelligence is indeed a construct, then we must believe that it can be assessed in some way. Sternberg and colleagues and others have based much of their assessment of practical intelligence on tacit knowledge, its acquisition and implementation (Sternberg, et al., 2000; Sternberg & Horvath, 1999; Sternberg, Wagner, Williams, & Horvath, 1995; Wagner & Sternberg, 1986).

Tacit knowledge, first named by Polyani (1962, 1966), refers to knowledge that is acquired through everyday experience with little or no environmental support (i.e., teaching) and is applied to solve problems toward the fulfillment of goals, particularly those that are personally valued (Sternberg, et al., 2000). Both the acquisition of tacit knowledge and its application have an implicit quality; no explicit instruction has guided either process. Consequently, tacit knowledge may be relatively difficult to articulate (Wagner & Sternberg, 1985).

Assessments of tacit knowledge (i.e., practical intelligence) have been created in a number of spheres—for the work environment (e.g., occupational situational judgment tests, Berman, Down, & Hill, 2002; Elliott, Stemler, Sternberg, Grigorenko, & Hoffman, 2010; Sternberg, Wagner, & Okagaki, 1993; Wagner, 1987; Weekley & Ployhart, 2006); in the military (Hedlund, Antonakis, & Sternberg, 2002; Matthew, Cianciolo, & Sternberg, 2005); as well as in schools and universities (Cianciolo et al., 2006; Insch, McIntyre, & Dawley, 2008; Leonard & Insch, 2005; Somech & Bogler, 1999; Sternberg & Rainbow Project Collaborators, 2006). The target of these assessments is individuals' tacit knowledge of the most socially appropriate and effective solutions to everyday problem situations, which may be occupational, academic, domestic or personal. These situations may require different kinds of knowledge, such as technological, organizational or social. Their common factor is that these areas of knowledge have been acquired tacitly, or solely through experience as opposed to explicit instruction.

A second aspect of practical intelligence that may be ostensibly tapped through assessment is the successful application of knowledge outside of the domain or context in which it was learned (e.g., school/academic setting), toward the solving of everyday problems. In these types of assessments, individuals may be asked to solve problems that occur in contexts such as shopping, cooking, common social situations or relationships, or local navigation, applying knowledge that they may have acquired in the academic setting, such as math skills, scientific knowledge, or geography facts. These tasks in themselves may seem mundane, but it is the underlying ability to apply one's knowledge efficiently and effectively within one's social and physical environment that is at the core of practical intelligence, and thus should not be overlooked in the development of gifted and talented individuals.

3 Assessing practical intelligence with Aurora

Aurora's practical subtests were designed to access different aspects of practical ability across the numerical, verbal, and figural domains, including the ability to work with money, mapping (numerical), decision-making, the interpretation of language for practical information (verbal), and the application of visual spatial skills that are learned implicitly. To give a sense of the range of Aurora's practical subtests, we describe each of Aurora's six practical subtests below, briefly.

3.1 Practical-verbal

Headlines presents newspaper-style headlines that have various interpretations; students must use their knowledge of both how the abbreviated style of newspaper headlines is used to convey meaning and of how they may be misconstrued. Responses are scored according to whether the student has captured the silly or serious meaning accurately; wording between students may differ.

Decisions presents scenarios in which a decision must be made. Students sort given information based on whether it constitutes an argument for or against the decision, leaving out irrelevant pieces of information. There is only one correct answer for each item.

3.2 Practical-numerical

Maps presents street routes on which students must draw a single line showing the shortest route to carpool between friends' homes and a movie theater, thereby applying their understanding of planning, distances, and map-reading to decide on a route that accomplishes their goal of efficiently. There is only one correct answer for each item.

Money Math presents scenarios in which people make various purchases as a group (sometimes while owing each other money) and must divide "bills" appropriately so that all parties have paid in full for their items, and are not owed money. There is only one correct answer for each item.

3.3 Practical-figural

Paper-cutting presents photographs of folded pieces of paper with shaded areas indicating intended cut-out areas. Students must imagine cutting this shaded area out while the paper remains folded. Four photographs of cut-out, unfolded pieces of paper are presented; students must use their knowledge of how the folding and cutting of paper works to determine which represents correctly the original folded, to-be-cut piece of paper. There is only one correct answer for each item.

Toy Shadows is a shadow identification exercise. Each item first shows photographs of a toy from various angles. Next, another photograph depicts the toy positioned on a table with a light shining on it. Students then choose from four more photographs the one which shows the exact shadow that would be projected using their understanding of how to "read" shadows for information, including consideration of the blurred edges and skewed proportions of some shadows. There is only one correct answer for each item.

Toy Shadows, thus, was designed to access a component of practical intelligence in the visual domain that involves knowledge that has been acquired tacitly or implicitly, that is, without explicit instruction or training. Unlike both the verbal and numerical subtests, which have often required substantial cultural adaptations, ***Toy Shadows*** generally remains unaltered (only needing direct translation of instructions) across cultures. To understand better the nature of the subtest and how it may contribute to our understanding of gifted students, we consider the information that shadows contain, the history of the study and uses of shadows, how individuals may acquire the skill of "reading" shadows, and how the ***Toy Shadows*** subtest is related to these.

4 The informative nature of shadows

The study of shadows within the domain of human visual perception has generated a wealth of empirically supported theories and conclusions about the nature of shadows, the information they provide, how they are used by the visual perception system, and for what purposes, although debates still remain (Dee & Santos, 2011).

First, shadows provide visual information on three aspects of the environment: the shape, size, slant and location and material nature (i.e., opaque or translucent) of the thing that is casting the shadow, generally referred to as the "caster"; the nature of the light source, including its orientation to and distance from the caster, and this source's width and intensity; and the surface upon which the shadow is being cast, including its texture or physical configuration (Casati, 2004; Dee & Santos, 2011). Leonardo da Vinci distinguished between two types of shadows: the attached shadow and the cast shadow. Attached shadows being those that an object casts upon itself, the sources of shading that help the viewer detect the texture and contours of an object. Cast shadows being those that an object casts upon a separate surface, such as the ground or a wall behind it. Inquiries concerning whether and how each piece of information yielded by shadows is used, in what combinations, at what level of complexity and for what purposes, have shaped the studies on shadows from the beginnings of science to today.

5 Three approaches to studying shadows

Human consideration of the shadow is age-old, starting with the use of shadows by early astronomers to study the relative motions of the earth, sun and moon, and their distances from each other; to confirm that the moon and other planets were of a similar nature to earth (via eclipses, particularly); and to measure time (Casati, 2007; Dee & Santos, 2011). The formal study of shadows themselves as mathematically consistent projections, however, began only in the early Renaissance, when painters began to struggle with the depiction of cast shadows in their work (which actually took about a century to satisfactorily achieve). Mathematicians of the time used painters' theories and practices for the depiction of shadows and systematized their measures (Casati, 2004; Da Costa Kauffman, 1993). Yet, how humans perceive shadows and cognitive aspects of shadow perception did not become the focus of scientific attention until the 20th century, with Piaget's account of children's explanations of how shadows are formed being among the first of such cognitive studies (Piaget, 1927).

Since Piaget, a few distinct scientific approaches to the use of shadows have become clear. First, there have been the formal, mathematically-centered scientific studies using shadows to discover or create related inventions, such as those studies conducted by early astronomers and by artists such as Leonardo da Vinci, who aimed to use shadows systematically to represent the third dimensional on a two dimensional canvas. Second, studies involving shadows have been used to explore the development of children's reasoning skills, as well as their understanding of the multidimensional nature of how shadows are created. And third, there have been many studies conducted in the field of visual perception that investigate how shadows are perceived and used every day by viewers to inform their understanding of the environment—the physical landscape and the shape, orientation, and motion of the items in it. The first type of studies we mentioned briefly above to provide some historical background. It is this third class of studies that we will discuss primarily in this chapter, as it pertains to the informative nature of shadows, how the human visual system perceives shadows, accesses or not their information, and acts upon that information, all of which encompass the body of implicit knowledge we all acquire about shadows. Yet we include now a brief discussion of the second type of studies—concerning the development of children's reasoning—to recognize the import of these studies and to better distinguish them from the third, more naturalistic, approach to studying shadows.

Since at least the time of Piaget, psychologists have been interested in how and when children's understanding of shadows emerges in the course of their development. Piaget's initial inquiries concerned children's conceptions of the sources of shadows, and he subsequently proposed the stages of cognitive understanding that build toward the accurate knowledge of how shadows are formed: stage one (about age 5), children understand shadows as emanating from the object itself or from some external source, such as a location or other object; stage 2 (about 6-7 years old), shadows are understood to be emanating from the object alone; stage 3 (about age 8), children can predict the orientation of shadows, with and without an actual light source; and stage 4 (about 9 years old), the child understands how a shadow is made (Piaget, 1927).

Later on, Inhelder and Piaget used shadows to ascertain the development of children's complex reasoning, employing a "projection of shadows task" (Inhelder & Piaget, 1958). In this task, rings of different sizes were placed at varying distances from a light source, producing various shadows on a screen. (Shadow size is directly proportional to the diameters of the rings and inversely proportional to the distance between the rings and the light source.) Children were asked to produce shadows of the same size using different-sized objects by varying an object's distance from the light–source. The task was designed to explore children's capability to work with two parameters at one time (object size and distance from light source) to accomplish a task. A set of similar studies have followed, using this same task for deeper exploration of the same phenomenon—complex problem-solving. For example, Siegler (1978, 1981) tested his rule model of problem solving—that children develop from unidimensional to multidimensional problem-solving capabilities continuously, rather than in Piaget's stages—using the projection of shadows task. More recently, Ebersbach and Resing (2007) looked at the same developmental capacity using the same task but with slightly different methodology, while also investigating individuals' implicit and explicit beliefs about the non-linear relationship between shadow, object size, and distance from the light source. Among other findings, they ascertained that while 4-year olds' implicit and explicit beliefs about the relationship between shadow, object size, and light source distance did not correlate, older children's and adults' did. That is, the youngest children's verbalizations of their understanding of shadows did not match their performance on the task.

Other developmental studies concerning shadows have been carried out with similarly aged children, but these, more in line with the third type of shadow studies, are focused on simple shadow perception and the types of shadow information that children are able to use. For example, supporting Piaget's description of children in stage 1, Hagen (1976) found that kindergarten children were unable to identify the correct direction of a light source based on the variations in shading and shadow in pictures. However, another developmental study, focusing simply on the ability to use shadow information to recognize certain physical details of objects, found that children as young as three years of age can discriminate between convexity and concavity in a photograph based solely on the orientation of the attached shadow (Benson & Yonas, 1973).

Yonas and colleagues (1978) further explored the developmental nature of sensitivity to shadow information in children ages three and four years old. These preschool children's sensitivity to cast-shadow information was investigated using pictures in which the presence and shape of the shadow cast by an object was varied. Results showed that three and four year olds can interpret shadows in drawings to ascertain the shape and implied three-dimensionality of an object. In a second experiment, three year olds, five year olds and adults similarly used shadow information to judge the distance and height of spheres in a picture. The older children and adults were further able to judge the relative sizes of the spheres using the shadows. Thus, while pre-school aged children may not yet be able to assess all aspects of a shadow situation (e.g., characteristics of the caster, the nature of the casting surface, and the distance, direction and intensity of the light source), á la the Hagen study (1976), young children can and do use shadow information to ascertain basic facts, such as the shape and location of an object in a two-dimensional representation. The next question we will explore, then, is what information from shadows is the human perceptual system naturally tuned to acquire, and for what purposes?

6 The peculiarities of the human perception of shadows

In their review of the literature concerning the perception and information content of cast shadows, Dee and Santos (2011) are particularly interested in contrasting the information that may be extracted from shadows by computer methods and what is generally perceived (i.e., deemed important by the visual system) by the human perception system when using shadow information to construct spatial representation from a visual scene. This comparison has brought up some interesting points about the peculiarities of human shadow perception, when considering the use of shadow information in naturalistic rather than academic settings.

First, the act of shadow perception itself would seem to be problematic, as shadows range in quality from having hard, clear outlines which make them appear "solid," to having vague, fuzzy borders. And yet, people do not tend to mistake shadows for solid object, nor do they appear to have any difficulty identifying perceiving shadows that have vague borders (Dee & Santos, 2011). That is, the human perceptive system seems to be attuned to identifying shadows in their various forms.

Yet, while shadows may provide a great deal of information about a visual scene (Casati, 2000), in particular on the respective locations of objects within a given scene (Mamassian, Knill, & Kersten, 1998), the visual system would first need to sort out to some extent which shadows match which objects. This matching process, the so-called "shadow correspondence problem" (Mamassian, 2004), can be computationally complex. Studies have found, however, that for practical purposes, the human visual system instead uses a heuristic to find a quick solution to shadow correspondence, that is, a coarse matching between objects and shadows. Mamassian (2004) asked subjects to determine the location of the light source in simple object/shadow wire model presentations, of which one third presented "impossible" or non-matching shadows. These "impossible" shadows could be read in three different ways, each indicating a different light source direction. Subjects appeared to read the shadow based on the correspondence of the object's center of mass to the shadow, ignoring the details represented by the object and shadow stem and cap.

Thus, over the last 40 years, while useful aspects of shadow information have been empirically explored, the ways in which shadows can be problematic or obscure understanding, have also been discovered. On the one hand, shadows can provide information about a three-dimensional object's shape (Cavanaugh & LeClerc, 1989). Shading can be used to differentiate convex from concave surfaces (Erens, Kappers, & Koenderink, 1993). Shadows can be used to infer the shape of the caster and its distance above the ground (Yonas, et al., 1978). They can influence the perception of depth of motion (Kersten, Knill, Mamassian, & Bulthoff, 1996), and aid in stereo depth perception (Puerta, 1989).

Yet at the same time, shadows can cause flat objects to appear three-dimensional (Bulthoff, Kersten, & Bulthoff, 1994), and non-rigid motion to appear rigid. Further, observers have been known to ignore shadow information when making judgments about convexity (Berbaum, Bever, & Chung, 1983); and shadows can impair judgments of illumination direction in situations involving slants and tilt (Mingolla & Todd, 1986). Some models of object recognition argue for the crucial importance of shadow to provide information on shape and depth, yet Moore and Cavanaugh (1998) demonstrated that identifying two-tone novel (computer-generated) objects that have cast shadows can be difficult, as the shadows introduce confusing edges. Tarr and colleagues (1998), meanwhile, showed that cast shadows can improve the recognition of novel geometric objects; changing the illumination condition (altering the shadow aspect of the object) or otherwise manipulating the shape of the shadow was observed to slow down object recognition (Castiello, 2001; Tarr, et al., 1998). And in a study of object recognition using naturally-occurring objects (i.e., fruits and vegetables; Braje, Legge, & Kersten, 2000), shadow presence appeared to have no effect on whether the object was recognized or not—that is, they neither impaired nor improved recognition of these natural objects. Interestingly, a study of cast shadows in art by Jacobson and Werner (2004) first observed the surprising relative absence of cast shadow in art, whereas attached shadows—those which give depth and form to the objects themselves—are ubiquitous. They concluded that, in the static representations of paintings, cast shadows did not seem to be critical to viewers' understanding of the pictorial scene and, in computer-generated images created to generate inconsistent shadows, incongruities or inaccuracies of cast shadow depictions were often overlooked, even in simple scenes.

These studies, among others, suggest that the human perceptual system uses (or ignores) shadows in particular ways. For example, it seems that the human perceptual system prefers to use shadow information for the interpretation of 3D motion over the cue of object size (Mamassian, et al., 1998). Yet, several studies have examined the way the human perceptual system deals with inconsistent shadows (Enns & Rensink, 1990; Farid & Bravo, 2010; Ostrovsky, Cavanaugh, & Sinha, 2005) and found that in general, inconsistencies between the position of the light source, the caster, and the shadow are overlooked. Bonfiglioni, Pavani and Castiello found that real objects with fake shadows did not affect verbal interpretation of the scene presented, although they did affect the way the object was reached for (2004). These results suggest that our perceptual system uses cast shadows as coarse cues for information, or as general indicators of coherence. The visual system may "read" a position estimation from cast shadows early on in processing, then filter shadows out as immaterial players in the physical space (Dee & Santos, 2011; Rensink & Cavanaugh, 2004). These studies also imply that shadow processing is both implicit (i.e., without conscious awareness) and automatic (i.e., carried out without active attention). Studies of cast shadow perception in people with brain injuries—whose ability to identify objects is effected by the presence of shadows, even though they cannot articulate explicitly the presence or absence of shadows—indicate that the ability to process and interpret cast shadows is not dependent upon conscious awareness of them, and is therefore implicit. We are usually unaware of the effect shadows have on our perception (Castiello, Lusher, Burton, & Disler, 2003). That is, people bring much more than they realize to their reading and understanding of shadows—from conscious observation to the unconscious habits and skills they have developed from "reading," for practical purposes, our three-dimensional world.

It is these implicitly learned skills that are the target of the Aurora subtest, ***Toy Shadows***.

7 A description of the *Toy Shadows* assessment

Toy Shadows, described above, is a collection of 8 multiple-choice items. Each item shows the child four views of a toy, then shows the toy oriented on a surface and the light source shining on it; that is, they see the caster and its orientation and distance from the light source. The child is then presented with four shadows, only one of which has been produced by the presented scenario. In essence, the child must match the information conveyed by one of the shadows to the given scene, or read the given landscape and correctly predict the shadow. The only varying element in each scene is the position of the caster (a uni-dimensional rather than multi-dimensional problem). What the child brings to the task is knowledge of how a shadow is produced and the implicit ability to read the rough cues of the shadow. What direction should the shadow be facing? What object-light orientation results in skinnier or fatter areas of shadow? Or longer or fore-shortened areas of shadow?

None of these skills are formally taught in any culture, that we know of, so we expect ***Toy Shadows***, which generally requires minimal translation and adaptation in different countries, to behave similarly across cultures. First, we will look at its performance as a test. Next, using confirmatory factory analyses (CFA), we will look at the test's factor structure within and across cultures for consistency to determine whether or not ***Toy Shadows*** travels well.

8 *Toy Shadows'* performance within and across countries

To evaluate the performance of the ***Toy Shadows*** test across cultures, the most recently collected samples from the US, Greece and Saudi Arabia were selected. Their details are provided in Table 1.

Table 1. Sample descriptions by country

Country	N	Females	Males	Mean Age (stdev)
Greece	171	92	79	11.13 (.84)
Saudi Arabia	542	248	294	11.29 (1.30)
US	130	61	69	10.90 (.91)

All of these data were collected in similar fashion, in schools in a group test setting, as part of the rest of Aurora's paper and pencil battery (an abbreviated sample from Saudi Arabia is used here, as the entire set has not yet been data entered). The US sample was collected from a generally culturally homogeneous suburban, private parochial school located in the middle of the country. The Greek sample came from diverse geographical ethnic and social backgrounds: half were drawn from a school at the center of Athens, and the rest from two rural schools in southern Greece. About 60 percent of the children were Greek in origin, and the rest from immigrant families. The Saudi schools from which we drew our sample were all government (public) schools, located in urban settings, with very limited diversity, i.e. over 90% native Saudi Arabian children, with the majority of the rest from nearby Arab countries such as Egypt, Jordan, Yemen and Syria.

8.1 Group performance and item analysis

First, group performance within each country was examined and item analysis was carried out to determine the fitness of these items to the three cultures. Table 2 shows the descriptive data for the children's performance in each country.

Table 2. Descriptive data by country

	N			Mean scores			SD		
Country	Total	Females	Males	Total	Females	Males	Total	Females	Males
Greece	171	92	79	3.26	3.35	3.16	1.75	1.73	1.79
Saudi Arabia	542	294	248	3.11	2.69	3.61	1.83	1.57	1.98
US	130	61	69	4.14	3.69	4.54	2.03	1.91	2.06

To determine the effects of gender on the total score of the ***Toy Shadows*** test for each country, we carried out an ANCOVA for each sample, in which the total score was the dependent variable, gender the independent variable, and age a co-variable, since all samples contain children with a range of ages. For Greece, there were no differences in the total score due to gender ($F_{(1,170)}$= .230, p=.632), but we did find gender effects in both the US ($F_{(1,129)}$=5.213, $p < 0.05$) and Saudi Arabian data ($F_{(1,532)}$=19.191, p<.001) with the females performing lower than the males.

To estimate the differences in the total scores between countries, we regressed both gender and age from the total score to adjust for the effects described above. We found significant differences between the countries ($F_{(2,840)}$=16.07, p<.001): the contrast *post hoc* with Bonferroni corrections showed that the US sample had the highest score, and as a group performed significantly differently from the Greek and Saudi Arabian children, with these latter groups performing equally.

Table 3 presents the means (frequencies), standard deviations and the correlations for each item-test. In this case, the mean is equal to the index of difficulty because there is no missing data. The correlation item-test shows the strength of the association between each item and the test. Further details are provided below[1]

[1] The data shown in Table 3 are interesting because it reflects how the items have different degrees of difficulty across countries. The percentage of items 1, 3 and 5 are similar in the three samples, around 50% of the children solved them successfully. Yet other items differentiate the countries, e.g item 8 is more

Table 3. Item means, standard deviations and item-test correlations

	Means (frequencies)			SD			Corr. Item-test		
	GR	SA	US	GR	SA	US	GR	SA	US
Item1	.84	.70	.65	.37	.48	.47	.212	.204	.325
Item2	.36	.52	.35	.48	.48	.50	.359	.285	.267
Item3	.44	.45	.48	.50	.50	.50	.137	.128	.262
Item4	.44	.62	.34	.50	.47	.49	.392	.377	.462
Item5	.49	.46	.45	.50	.50	.50	.180	.135	.189
Item6	.30	.52	.39	.46	.49	.50	.251	.262	.285
Item7	.15	.32	.18	.36	.38	.47	.252	.276	.204
Item8	.24	.54	.27	.43	.45	.50	.241	.401	.498

The correlations for the total scores across the countries (Table 4) show that all three tests are related, with the Saudi Arabian and Greek test performance being somewhat more closely related to each other than to the US test performance.

Table 4. Correlations between total scores (including all eight items)

	GR	US	SA
GR	1		
US	0.733	1	
SA	0.937	0.632	1

When tested with the null hypothesis $r = 0$, the correlation between the total scores for Greece and the US was significant ($t_{(6)} = 2.64$, $p < 0.05$), as for between Greece and Saudi Arabia ($t_{(6)} = 6.57$, $p < .001$). However, the correlation between the US and Saudi Arabia total scores was not significant ($t_{(6)} = 1.998$, $p = 0.092$).

8.2 Confirmatory Factor Analysis

difficult for the US and Greek samples than the Saudi Arabian; the same occurred with items 4 and 6; and item 7 is difficult for all of the countries—only 15% to 32% answered it correctly.

Confirmatory factor analysis (CFA) was carried out based on the hypothesis that all items of the test load on one factor, i.e., the ability to "read" shadow information, which we posit reflects an aspect of practical intelligence in the figural domain. Baseline models were first created for each country's sample using LISREL 8.54 (Phase I; Joreskog & Sorbom, 2003). After noting that item 3 demonstrated a very low loading across two of the three countries (see also the correlation item-test above), it was deleted for the subsequent analyses. After combining the samples and deleting item 3, the reliability (Cronbach's alpha) of the test was 0.577; previously, it had been 0.567). Thus, an altered subscale with only 7 items was considered in the rest of the analyses.

Next, configural invariance in a multi-group model was examined (Phase II); that is, each country's data was tested for fit to a one-factor model that was consistent across all countries by constraining the variance/ covariance matrices to be equal across countries. This constrained model fit the data well. Findings suggested that regardless of culture, children showed fairly invariant performance in ***Toy Shadows*** test correlation patterns. Since any factor structure is derived from these variance/covariance matrices, results revealed that the ***Toy Shadows*** measures the same constructs, the factor structure across these four cultures should be very similar. Measurement equivalence was then tested to see if factor loadings corresponded across the countries (Phase III), and the factor-loading equivalence suggested that the ***Toy Shadows*** measurement scale is indeed the same across the countries. In Phase IV, we tested the hypothesis that in our model, the factor structure, loading factors and error variance are equal across countries.

Finally we compared the models in pairs, computing the S-$B_X{}^2$, and the observed p-values were not significant in the comparison between the Phase II and III models

($X^2_{(12)}$=20.09, p = 0.065), and between the Phase II and IV models ($X^2_{(26)}$=38.46, p = 0.054), confirming their similarity. If we take the ΔCFI criteria—the more practical criteria, whose difference across the models is 0 (Cheung & Rensvold, 2002)—we can conclude that the ***Toy Shadows*** test is invariant in its factor structure, factor loadings and variance error across the three countries. These analyses are summarized in Table 5 below; details are presented in a footnote.[2]

Table 5. Multi-group goodness-of-fit indices for 7 items

Model	S-BX2	df	X2/df	CFI	RMSEA	RMSEA 90% CI	SRMR	ΔS-BX2	Δdf	ΔCFI
Phase I: Baseline model										
US	12.01	14	.857	1.0	.000	.000 – .073	0.069	-	-	-
Greece	9.69	14	.691	.86	.000	.000 – .050	0.073	-	-	-
Saudi	22.86	14	1.63	.99	.034	.000 - .059	0.057	-	-	-
Phase II: Configural invariance										
	45.1	43		1.0	.013	.000 –.043	0.073	-	-	-
Phase III: Measurement Equivalence										
	67.54	56	1.20	1.0	.027	.000 –.048	0.063	20.09	12	.00
Phase IV: Scalar Invariance or structural model										
	85.91	70	1.22	1.0	.028	.000 -.047	0.063	38.46	26	.00

9 Measuring shadow perception: Practical or not?

In the search for new ways to identify gifted and talented individuals, Aurora's ***Toy Shadows*** make an unconventional contribution, but a suggestive and important one in attempting to represent one aspect of an area of cognitive ability not usually considered in

[2] The multi-group comparisons were performed using LISREL 8.54. Due to the dichotomous nature of the data, we used the diagonally weighted least squares (DWLS) like estimation method with polychoric correlation, and asymptotic covariance matrices were applied. We used the RSMEA to evaluate the fit of the structure in the data to the model, with RMSEA below .05 indicating a reasonable fit when its upper confidence interval is below .08. The comparative fit index (CFI) was additionally used, with a value between .90 and .95 indicating an acceptable fit, and above .95 indicating a good fit (Kenny, 2008). The ratio between the X2 and df was considered as a fit index, and the values close to 2.0 or 3.0 were considered good fits for the v2 to df ratio (Bollen, 1989). The Standardized Root Mean Square Residual (SRMR) is an absolute measure of fit and is defined as the standardized difference between the observed correlation and the predicted correlation. It is a positively biased measure and an absolute measure of fit. A value less than .08 is generally considered a good fit (Hu & Bentler, 1999).

the search for gifted children. It must be noted that ***Toy Shadows*** does not constitute an argument for implementing the study of shadows in school, but points more importantly to the assessment of skills and abilities that are not explicitly taught, in this case those that are related to visual perception. But what makes ***Toy Shadows*** worthy of consideration?

In the analysis of group performance on ***Toy Shadows***, we see that children in different cultures may perform differentially, as the Saudi Arabian and Greek samples perform much more similarly to each other than to the US sample. In addition, performance on ***Toy Shadows*** may be differentially influenced by age and gender, with the US and Saudi Arabian samples being affected by both age and gender, and the Greek by age only. These differences may be explained in part by the fact that the US sample was drawn from a single private school in the US, while both the Greek and Saudi Arabian samples included several schools each, both urban and suburban. They may also be explained by possible cultural and environmental differences that may be explored in future studies.

Yet, in spite of these differences, CFA analyses show that the ***Toy Shadows*** assessment behaves consistently, with the 7 items contributing to a single factor, across all 3 cultures. Whatever ***Toy Shadows*** measures, it appears to focus on a single latent factor, and its items perform in similar patterns across 3 very different samples. In the future, studies with larger, more representative samples may be carried out to validate the assessment.

What is this latent factor? On the surface, it has been argued that ***Toy Shadows*** appears to target more analytical abilities, as children ostensibly match the produced shadow choices with the given toy-light orientation. Yet, according to a sample of over 2,000 children who have taken the entire Aurora paper and pencil battery, ***Toy Shadows'*** performance is not particularly related to any of Aurora's analytical subtests. In fact, across Aurora's 16 other triarchically-related subtests, ***Toy Shadows***' correlations range from -0.028, with one of the creative subtests, to .361, with ***Toy Shadows***' companion practical-figural subtest, *Paper-cutting*. ***Toy Shadows***' highest correlations with Aurora's highly analytical IQ portion (Aurora-g; 9 subtests) are .263, .267, and .284; these are with the three figural subtests, which are analogy, series and classification multiple choice tests, respectively.

The ability tapped by ***Toy Shadows***, then, would appear to be quite distinct from those tapped by analogical reasoning tasks, or computational tasks. It is essentially distinct, also, from Piaget's projection of shadows task. In fact, as we have tried to show above, the human perception of shadows is not straightforward. It is often not precise, not analytically executed but rather as a rough estimation that may get discarded once it has been registered—a practical practice of "simplified physics" (Cavanaugh, 2005, p.301) that gets us through the day. It also allows us to appreciate and be "fooled by" even the most unrealistic depictions of light and shadow in works of art. And it explains why, while easily generated through algorithms on a computer, shadows can be the painter's bane as one of the greatest challenges of the craft. That is, while perhaps consciously and analytically understood, shadow perception is generally learned and executed unconsciously (an explanation, also, for the inability to articulate the behavior of shadows even though one can predict it, at an early age). As such, this ability may stand as an aspect of practical intelligence that represents a form of visual practice and understanding that has developed over time, is exercised and strengthened generally without conscious effort, and that may constitute meaningful differences between individuals. In gifted and talented individuals who harbor these quiet strengths, recognition and conscious harnessing of these advantages may help these children grow their abilities, use them to compensate for the weaknesses, and thereby increase their potential for success in life.

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