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University entry score: Is it a consideration for spatial performance in architecture design students?

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Abstract

Purpose – The purpose of this paper is to provide an insight into the relationship between students' spatial ability and their university entrance score (Australian Tertiary Admissions Rank [ATAR]). The ATAR provides entry into university studies but does not necessary provide a good measure of students' spatial skills. Spatial abilities are fundamental to success in many design courses. This paper aims to show whether the ATAR is a good predictor of spatial skills and considers the implications of this.
Design/methodology/approach – Students entering university design courses in architecture were tested three times during their first year using a three-dimensional (3D) Ability Test (3DAT), an online psychometric test of 3D spatial ability. The students' results in 3DAT were then compared to students' ATAR scores using a Pearson's correlation test were also conducted to assess the relationship between ATAR and spatial performance.
Findings – There was no correlation between ATAR and spatial performance. Therefore, there was no relationship between an individual's ATAR and their spatial performance upon entering university.
Research limitations/implications – Participants were required to select their ATAR from ranges, i.e. 71-80, 81-90 and 91-100, which meant their exact ATAR was not recorded. This meant that the participants were clustered, making it difficult to establish a linear relationship that was a true reflection of the population.
Practical implications – Initiatives to support students entering design courses may be necessary to compensate for the range of spatial skills students possess when entering university because of their school experiences.
Social implications – Individuals who have strong spatial skills are able to perform spatial problems faster and more efficiently than those with weak spatial skills. High spatial performance has been shown relate to performance in areas such as mathematics science technology and design.
Originality/value – This paper fulfils the need to better understand the diversity of spatial abilities students have on entering design courses.

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Keywords Architecture, Design education, Design cognition, Spatial abilities, University entry score, Design ability

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Introduction

Design is a natural human activity present in many professions (such as engineering, industrial design and architecture). The design activity when utilised by the design professions provides a significant force for innovation and change in our societies. Despite the fact that the activity of design and the activity of science are tightly linked, design can be contrasted to science in that it is considered to be about imagining and synthesising new realities, rather than analysing and describing existing ones. Design can also be contrasted to art, as it is essentially guided by human purposes and is directed towards the fulfilment of intended functions. The distinctive nature of the design activity, as illustrated by this emphasis on novelty and usefulness, makes design fundamental to modern society. As such design is important to our society, but there is a dearth of information about the range of skills of students, as they enter university to study design-based courses.

Spatial ability was traditionally considered an innate ability that moderated learning (Snow, 1977). Yet, Piaget and Inhelder (1971) presented a constructivist theory of development. This theory showed spatial ability as a factor of intelligence that had the potential to be developed, even throughout adulthood. Spatial ability can be hierarchically developed through learning experiences over a lifetime (Piaget and Inhelder, 1971). Lohman and Nichols (1990) outlined the conditions for development that are reliant on both the type of learning and the duration of training. More recently, training programmes, such as Potter and Merwe (2003) in their adoption of Piaget's theory, have significantly improved the spatial ability of university students through action, mainly imitation of actions of an instructor allowing students to see the steps involved in the design process. Actions that have developed significant spatial skills improvement for students include sketching, technical drawing and modelling activities (Potter and Merwe, 2003; Sorby 2007). Other successful programmes have utilised workbooks but also included activities, e.g. interpreting blueprint sketches, drawing hidden views and visualising of orthographic drawings (Hsi *et al.*, 1997).

Literature review

Spatial ability is a complex construct that encompasses many different spatial factors (Williams *et al.*, 2008; Quaiser-Pohl and Lehmann, 2002). Currently, there is not a universally accepted definition of spatial ability (Caplan *et al.*, 1985; Maier, 1998). This is partially due to its complexity and a tendency within the literature to apply different terms to similar factors and to use different tests to assess the same factor (D'Oliveira, 2004; Voyer *et al.*, 1995; Maier, 1998).

Though illusive to define, it has been suggested, however, that spatial ability can be represented in three different factors: "spatial orientation, spatial relations, and spatial visualisation" (Lohman, 1979). Spatial orientation is the way a person relates to space and their ability to distinguish the differences between objects. Spatial relations are the way objects are placed in relation to each other. Spatial visualisation is the ability of a person to mentally assemble objects or imagine how objects relate to each other. (Ivie and Embretson, 2010). All these attributes are important to a designer and their ability to design and also to collaborate with other designers in collaborative design.

The importance of spatial ability is highlighted through its everyday applications, which includes navigating environments, recalling locations, problem-solving skills and identifying and mentally manipulating objects (Pellegrino *et al.*, 1984; Tzuriel and Egozi, 2010). Individuals who have strong spatial skills are able to complete these tasks faster and more efficiently than those with weak spatial skills. This is due to their enhanced ability to generate, retain, retrieve and transform visio-spatial information (Contreras *et al.*, 2012).

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Spatial visualisation skills are fundamental to the design process, including such fields as architecture, industrial design and engineering, allowing those involved in these activities to manipulate and evaluate a new design object mentally, especially in the conceptual stage. Once the new object is formulated, it is best conveyed externally through non-verbal forms of communication such as sketching and modelling (Cross, 2004). Likewise, the construction of three-dimensional (3D) form is another essential tool for designers (Cross, 2004). At times, not all the components of a visual image can be verbally communicated (Akalin and Sezal, 2009); by creating a physical representation of an innovative idea, all the aspects of the object such as colour, materials and size ratios are evidenced (Akalin and Sezal, 2009). Furthermore, aptitude in sketching and 3D modelling is highly correlated with spatial ability (Mehrabian, 2009). Therefore, spatial ability facilitates the skilful use of tools essential in the design process. In this respect, spatial ability is imperative to design-based disciplines such as *architecture* or the building or realisation of the designed forms as done by *construction management* (Williams *et al.*, 2008).

The significance of spatial ability is further highlighted in the predictive ability of tests of spatial performance. The literature consistently reports that performance on tests of spatial ability correlate positively with academic performance. That is, high spatial performance has been shown to relate to performance in areas such as mathematics, science, technology and design (Maier, 1998; McGee, 1979; Smith, 1964; Schwizer *et al*., 2007). Research has also shown that spatial performance is one of the most reliable indicators of success in graphics based courses (Blasko *et al.*, 2004) as well as predicting job performance in a variety of design fields or disciplines (Colom *et al.*, 2003).

The relationship of spatial abilities and success at university

Sorby (2007) reported that 3D spatial skills have a direct correlation to success in a variety of careers including engineering and science. At a time when visualisation skills are increasingly important to engineering students, engineering graphics (the primary course where students first learn visualisation concepts) receive less emphasis, in many cases, dropped from the engineering curriculum. Sorby provides evidence of the successful outcome achieved by a bridging course aimed at improving prerequisite 3D spatial skills needed to succeed in graphics courses.

Success in graphics courses requiring spatial ability skill is routinely cited as having negative consequences leading to under performance. Adanez and Velasco (2002) suggests that difficulty coping with graphics-based courses lead to poor academic performance that, in turn, contributes to not continuing with their studies. Potter and van de Merwe (2001) support this position, identifying spatial ability and visual imagery have an influence on academic performance in engineering. They highlight high failure rates among engineering students across several universities and relate the importance of early detection of students with difficulties. In particular, Potter and van der Merwe maintain that a student's level of spatial ability at the time of intake to university is an important factor in their overall academic performance. They suggest that there would be value in appropriate graphics courses being offered at secondary school level. They have a strong belief that improvement in spatial ability is possible with appropriate intervention prior to participation in university-level graphics courses. They report that students vary in spatial ability and those with low scores are at a higher risk of failing engineering subjects which involve spatial skills such as a component of graphics-based subjects. As the tertiary sector does not have a strong influence over secondary education, it becomes more critical for the sector to have a direct focus on improving spatial ability in its first-year graphical communication courses. Also, training has the potential to develop spatial skills with particular benefits for low performers.

Lajoie (2003) goes further by highlighting that there is evidence in aptitude research that supports the concept of low-ability learners gaining more from training than high-ability individuals. Interestingly, Lajoie suggests that training on some spatial tasks show greater levels of improvement for women than for men who undertake the same training.

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Strong and Smith (2001) indicate that spatial visualisation (a domain of spatial ability) is recognised as a predictor of success in several technology-related disciplines. They consider spatial visualisation skill levels coupled with changes in technology to be an argument for more attention to curricula and teaching that focuses on spatial cognition. The authors also contend that it is the type and length of experiences that have the greater impact on spatial ability and may compensate for other factors like age and gender. Of special importance to this paper is a strong observation from Strong and Smith who identify that there are many spatial ability tests in existence, but many previous studies have been limited in size and scope with variances in testing methods that question the validity of these studies.

How has spatial ability been taught to date?

The conventional approach to teaching spatial ability is partly passive (Sutton *et al.*, 2008). In this sense, *passive* refers to the actual learning of 3D concepts though sketching, which is often used to demonstrate and reinforce what has been learnt. Participants learn from observing instructor-based demonstrations that primarily focus on scaled models of objects encased in plastic frames (Duesbury and O'Neil, 1996). Often, the views of an object are manually projected onto planes represented by the plastic frames to illustrate what is seen from different viewing directions, and to demonstrate what changes occur when an object is moved. Such learning techniques provide very little hands-on experience and encourage students to rote-learn a set of rules rather than developing a deeper understanding. Rote learning can be effective for simple and familiar examples but is unreliable for complicated and novel structures (Sutton *et al.*, 2008).

Most design students receive very little formal training in the skills of spatial manipulation. Instead, it is generally left to their natural ability, or *ad hoc* experiences, (sometimes as graduates) to attain these skills. However, engineering programmes often include drawing in the first year of study because it is regarded as a core skill needed by students for subsequent subjects in their programme. This is where specific efforts to improve spatial ability should occur.

The teaching of drawing skills often involves drawing processes where 3D drawings are redrawn as two-dimensional (2D) drawings (orthogonal projections), or 2D views are redrawn into a single 3D view (isometric). There is often no skill development in the transfer of concept images to formal drawing forms or even the documentation of real objects. Drawing is often taught in a procedural manner rather than through the deeper learning processes which encourage a diversity of approaches to learning. In many cases, the learning is somewhat incidental rather than deliberate.

The above contextualises the use of spatial abilities in design-related programmes of study. Undergraduate students are dependent on these abilities to facilitate the conceptualisation, generation and communication of design projects (Sutton and Williams, 2010). As a result, to be competitive in the global industry, graduates rely heavily on having acceptable spatial skills in the everyday conduct of their work as expected in their occupations. Therefore, course work for design disciplines should include components that enhance their spatial skills, this would include practical activities including sketching and modelling (Cross, 2004). Despite the inherent difference in the design disciplines, courses of study should expose students to learning experiences, which develop spatial skills.

Though it must be considered how well-prepared students come to university to engage in spatial problems. Previous studies (Blasko *et al.*, 2004; Potter and Van der Merwe, 2001) indicate that there is a correlation between spatial ability and academic performance, as individuals with strong spatial ability perform better academically, particularly in design-based disciplines. However, it has not been ascertained whether this relationship can be extended to a more general test of academic performance, the Australian Tertiary Admissions Rank (ATAR), *the Australian university entry score*. This study aims to determine whether the *ATAR* is a reliable predictor of spatial ability.

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What is an ATAR?

The study reported in this paper related students' spatial ability scores to the ATAR. The ATAR is a percentile awarded to students upon completion of Year 12 to be used in their application for undergraduate-entry university programmes. The number functions as a rank of all students entering the tertiary education system, based on the number of students in Year 7 (first year of high school). The maximum rank attainable is 99.95 with a minimum of 30.00 and increments of 0.05. The process used to calculate an ATAR is as follows: scores for each of the student's subjects is scaled (adjusted up or down depending on the strength of competition amongst the cohort of students studying the subject that year). The scores are added together to form a number called an "aggregate", the student with the lowest aggregate on one end and the student with the highest aggregate on the other end. The ATAR is a percentile and represents how many students got a lower aggregate. An ATAR of 80.00 indicates that a student is in the top 20 per cent of his or her cohort.

Spatial performance and the ATAR

When assessing the spatial performance of design-based disciplines, it is important to assess factors other than gender that may have an impact upon spatial ability (Blasko *et al.*, 2004; Doyle *et al.*, 2012; Linn and Peterson, 1985; Potter and Van der Merwe, 2001). These factors include academic performance, previous spatial experience and age among others. These factors are especially relevant when a study is conducted in a university or educational setting.

As discussed previously, a positive relationship between *academic performance* and spatial ability has been established (Blasko *et al.*, 2004; Potter and van der Merwe, 2001). However, no study has investigated the relationship between the ATAR and spatial performance. It should be noted that *ATAR* and *academic performance* are not entirely synonymous terms. An individual's *ATAR* score is a measure of their general academic performance at high school across a wide range of subjects and is often used as a predictor or estimate of their ability at a tertiary level. On the other hand, academic performance can refer to an individual's performance in fewer and more specialised subjects such as those in a university degree. To avoid confusion, this study uses the term *academic performance* as a reflection of an individual's results at university.

The lack of studies investigating *ATAR* means that it has not been established whether the same positive relationship between academic performance and spatial ability also occurs for *ATAR* and spatial ability. That is, can an individual's *ATAR* score be used to predict their spatial ability and, therefore, their potential for success in a spatially intensive degree? This point needs to be investigated, as most universities base their admission requirements on an *ATAR* cut-off. If *ATAR* scores are an accurate representation of the individual's spatial ability, then using it as the sole admission requirement may be justified. However, if *ATAR* is not correlated with spatial ability, then other admission requirements may be beneficial because of the importance of spatial ability within design-based disciplines.

The test used in the study

The instrument used to test student was the 3D Ability Test (3DAT) a psychometric test of 3D understanding that compared the spatial abilities of participants. The 3DAT consists of five subtests representing different forms of spatial ability and test items within each. It is a computer-based instrument that measures choice accuracy and response time. The studies were conducted under laboratory conditions and in accordance with established psychological methodology protocols. Data were analysed using standard and appropriate statistical procedures. The 3DAT is delivered on a computer using psychological experimental research software (SuperLab Pro). It consists of 30 items divided into six subtests.

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Participants

Participants were first-year students enrolled in the Bachelor of Architecture course at the University of Newcastle. They were recruited in two cohorts, 2010 and 2011, through participation in a Drawing unit (semester one) and a computer-aided design unit (semester two). Two hundred and nineteen participants were recruited, 117 in 2010 and 102 in 2011. Refer to Table I for the total of males and females within each cohort. Seven participants failed one or both of the courses in 2010 and repeated them in 2011. In the instances when these participants would potentially bias the results, their 2011 data were removed.

Table I. Sample sizes

Year	Male	Female	Total
2010	67	50	117
2011	59	43	102
Total	126	93	219

Stimuli

Participants were tested using the 3DAT, an online psychometric test of 3D spatial ability. Although many tests of spatial ability were available, the 3DAT was chosen because it had undergone rigorous psychometric testing in its development. For example, the test-retest reliability is 0.85 (Sutton, 2011). The 3DAT consists of five subtests, *mental rotation* (MR), *building representation* (BR), *2D to 3D transformation* (TR), *mental cutting* (MC) and *dot-coordinate* (DC) where each measures a different factor of spatial ability (see Table II), and they collectively measure the spatial ability construct (refer to Figure 1).

Testing spatial ability

3DAT is a computer-based instrument that measures choice accuracy and response time. In its present form, the 3DAT consists of five subtests. Each subtest aims to measure separate factors of spatial ability, often referred to as elements or spatial skills.

The 3DAT is delivered online and can be used for research purposes or as a spatial diagnostic test. It consists of 30 items that are divided into five subtests. The test items are all made up of straight lines and flat planes, but they vary in form and are novel in design. Below is a description of the broad areas that define the subtests:

• *Mental cutting*: A 3D view of an object intersected by a cutting plane is presented. The idea is to identify the resulting 2D shape of the surface when the top portion of the object is removed. Participants choose from four options. This subtest identifies a spatial skill defined as spatial sections.

• *Building representations*: A 3D view of an object based on an arrangement of cubes is displayed with front and right views clearly labelled. Participants are asked to identify the correct 2D back view of the object from four given options. This subtest identifies a spatial skill defined as spatial perception.

Table II. 3DAT subtests and the spatial factor they measure

Subtest	Spatial factor measured
Building representation (BR)	Spatial perception (SP)
Transformation (TR)	Spatial reasoning (SR)
Mental cutting (MC)	Spatial sections (SS)
Mental rotation (MR)	Mental rotation (MR)
Dot coordinate (DC)	Spatial orientation (SO)

Source: Sutton (2011)

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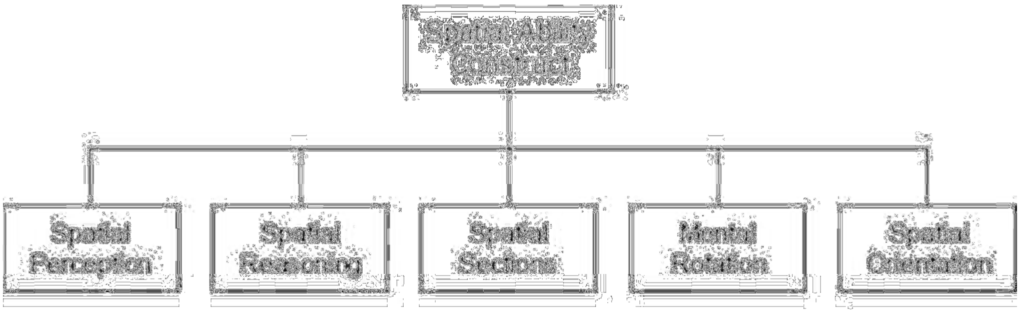
Figure 1. The spatial ability construct



Source: Sutton (2011)

• *Transformation*: A top view of an object in 2D format is presented and a viewing direction is provided as a reference point. The object is an arrangement of cubes with numbers in strategic positions to indicate the 3D shape of the object. Participants decide from four 3D options which one matches the given viewing direction. This subtest identifies a spatial skill defined as spatial reasoning.
• *Mental rotation*: Participants decide if a rotated isometric projection of an object matches the isometric projection of a standard or its mirror image. The object on the left is always in the same position and is the referent. The object on the right can be the same or the mirror image of the referent and its orientation in the XY plane can be different.
• *Dot coordinate*: Participants are shown an isometric projection of a 3D Cartesian coordinate system and a text description of the position of a point in that system (Bore and Munro, 2002). From four orthogonal projections, participants choose the projection that corresponds to the description. This subtest identifies a spatial skill defined as spatial orientation.

The five subtests cover a comprehensive range of different factors of the spatial ability construct and provide a detailed understanding of the spatial ability of participants. Each subtest consists of six test items in which the participants are presented with a stimulus and asked to pick the correct answer from four options. The exception is *mental rotation* in which the participant is presented with two stimuli and must decide whether they are the same or different. An example of each subtest is shown in Figure 2.

Procedure

The participants completed the 3DAT upon entering university. The online method of delivery allowed the 3DAT to be conducted within the participants' regular tutorial time. Participants were required to log in into the 3DAT using their University of Newcastle student credentials, i.e. their unique student ID. Before beginning the test, the participants were required to enter demographic information including gender, discipline, age and ATAR, from the drop-down options available.

The five subtests of the 3DAT were then presented in random order. At the start of each subtest, participants were presented with an instruction slide. This slide included information about the subtest and an example test item (similar to those shown in Figure 2). Participants were not given feedback on the example test item. Once the participants understood the instructions, they clicked "start when ready" to proceed with the test items.

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The six test items for the first subtest were then presented, one at a time, in Random order. The participants responded by selecting the answer they thought was correct, which advanced them to the next test item. If the participant failed to respond after 150 seconds, the test item would time out and automatically progress to the next item. The participants' accuracy and response time was recorded for each test item.
After completing the 3DAT, participants were given feedback on their performance, including the number of correct responses for each subtest and their overall score as a percentage. They also had the option to have a summary of their results sent to them via a confidential email. This allowed participants to monitor their spatial performance over repeated attempts of the 3DAT. Participants also had access to the 3DAT following testing, allowing them to reattempt the 3DAT if they were not satisfied with their original attempt. The test was also seen as a good learning experience for the students and the support of the system to provide feedback and assist in the development of spatial skills was seen by the students as a positive aspect of the experience.

Limitations of the study

A study of this nature is limited by the inability for the research team to be able to access the students' exact ATAR score, instead a series of ranges had to be employed. As such, it was more difficult to establish an accurate relationship between ATAR and spatial performance. Also, the analysis of ATAR effects had the added limitation of having unequal sample sizes across the ranges. This resulting from the limited range of ATAR scores possible at a University, entry into Architecture requires an ATAR of 75 or greater. What also was restrictive in fully understanding the student profile was the fact that it is not possible to establish the school subjects that contributed to the students' ATARs. Having an understanding of the subjects that were involved in each student's ATAR would allow a better understanding of the relationship of the school experience and the impact on each student's spatial ability.

Data analyses

The linear mixed modelling (LMM) procedure was used to analyse differences in spatial performance for the 3DAT. The LMM was chosen, as it accounts for the differences in sample sizes across repeated attempts because not every participant completed the 3DAT at the start of their programme (see Table III). The LMM was also used to compare the 2010 and 2011 cohorts to determine whether the two cohorts significantly differed in spatial performance on the 3DAT and whether they could be combined.
A scatterplot and a Pearson's correlation test were also conducted to assess the relationship between *ATAR* and spatial performance, and between *previous experience* and spatial performance. One-way analysis of variance (ANOVA) was conducted to analyse the differences in spatial performance.

For all one-way ANOVA and independent *t*-tests analyses, the 2011 data for the seven participants that repeated one or both of the courses was removed to ensure independent samples. These data were also removed when the 2010 and 2011 cohort was combined for the LMM analyses.

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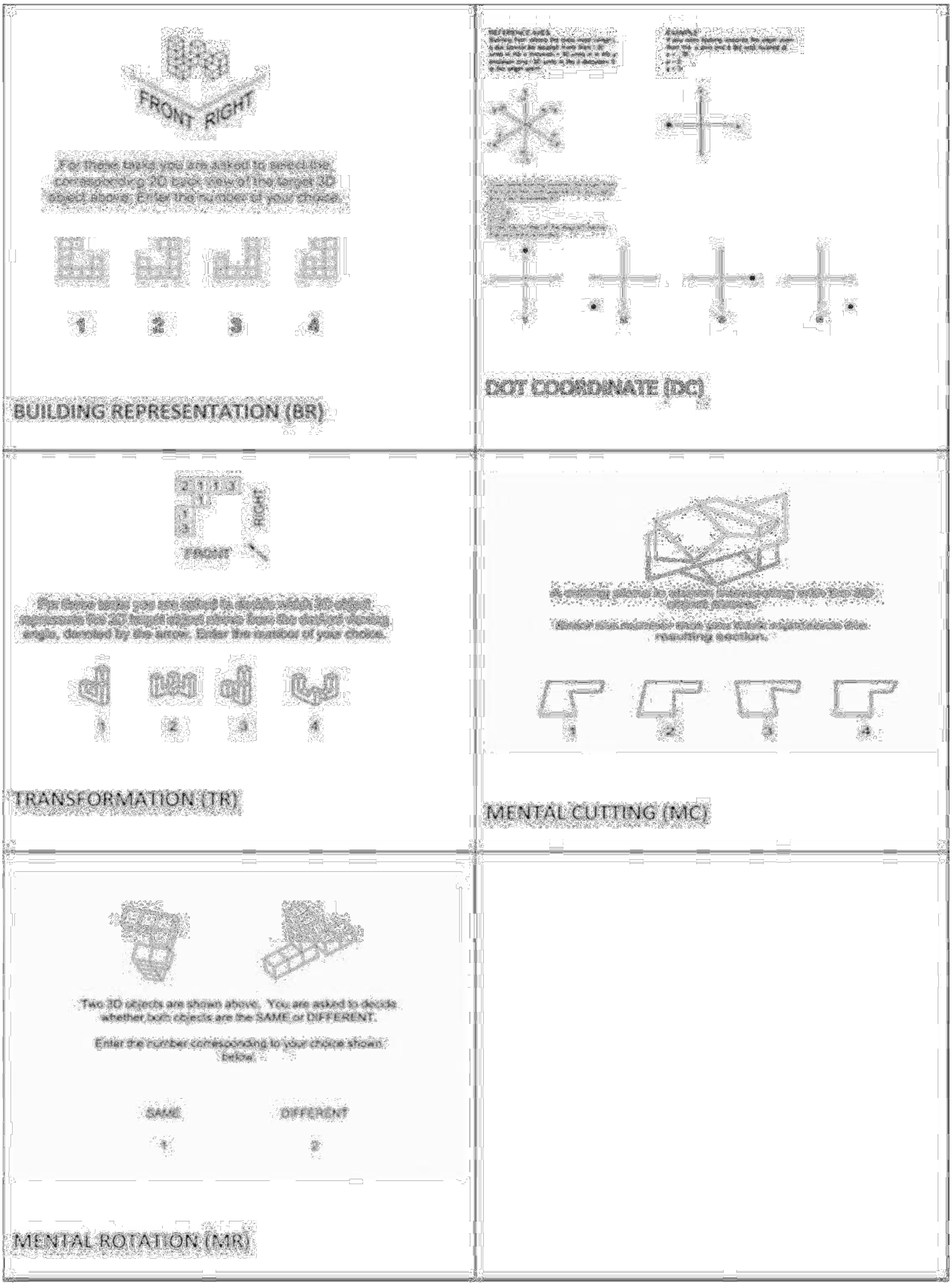
Figure 2. Test item examples for each subtest of the 3DAT



Source: Sutton (2011)

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Spatial ability compared to ATAR

A Pearson's correlation coefficient was calculated to analyse the relationship between *ATAR* and spatial performance. There was no correlation between *ATAR* and spatial performance (*r*(121) _ 0.08, *p* _ 0.40). Therefore, there was no relationship between an individual's *ATAR* and their spatial performance upon entering university to study architecture (see Figure 3).

A one-way ANOVA was also conducted to check for differences between the three levels (71-80, 81-90 and 91-100). Participants with an ATAR greater than 91 (*M*_19.89, *SD* _ 3.98) performed better than participants with an ATAR of 71-80 (*M* _ 19.07, *SD* _ 4.14) and 81-90 (*M* _ 18.74, *SD* _ 4.42); however, the differences were not significant (*F*(2, 120) _ 0.75, *p* _ 0.48). It should be noted that the samples sizes were unequal for the ATAR groups (Table IV).

One-way ANOVAs were also conducted to test the two cohorts (2010 and 2011) individually. There was no significant effect of ATAR on spatial performance in either 2010 (*F*(2,60) _ 1.81, *p* _ 0.17) or 2011 (*F*(2, 57) _ 0.38, *p* _ 0.69) (Table V).

Table III.
Sample size

Cohort	No. tested
2010	88
2011	80
Total	168

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Figure 3. Scatterplot for spatial performance by ATAR

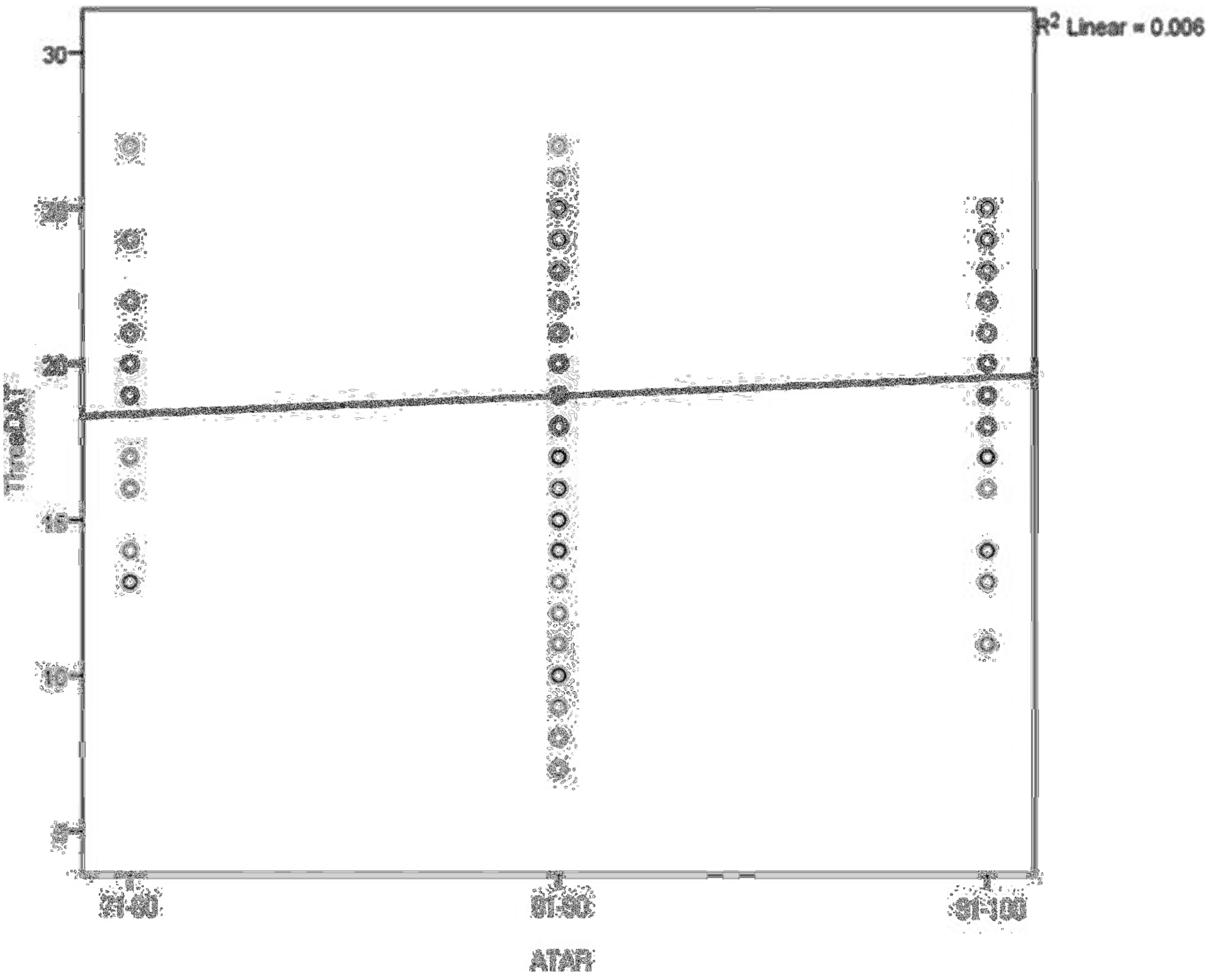

Table IV.
Sample size for ATAR

Year	71-80	81-90	91-100	Total
2010	8	39	16	63
2011	6	42	12	60
Total	14	81	28	123

Table V. Mean and standard deviation for ATAR

	71-80		81-90		91-100	
Year	M	SD	M	SD	M	SD
2010	20.13	4.29	18.18	4.70	20.44	3.50
2011	17.67	3.83	19.26	4.14 1	9.17	4.16

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Conclusions

Despite the study reported here being confined to architecture students, it is important to appreciate that the issue of spatial performance crosses all design-related disciplines. Initial differences that exist prior to tertiary education have implications for design-based undergraduate degrees. When working in industry, designers have to be efficient in communicating non-verbally and interpreting and creating technical drawings (Wai *et al.*, 2009). Subsequently, to remain competitive in a global industry, Australian universities have to produce design graduates with a higher spatial ability (Leopold *et al.*, 2001). Therefore, the requirement to attract students with high spatial skills is important. Course coordinators should ensure that potential applicants know the design-related components of the course. Furthermore, the high spatial ability of students who enrol in design has implications for the courses of study themselves.

Australian design companies are now competing with that of the world for major design projects. The high initial spatial ability of the students may be an opportunity for course work to start off more in-depth and move more quickly. An increase in the difficulty of spatial tasks has the potential to further develop the spatial ability of design students, placing them at an advantage in the workforce.

The results of the study, reported in this paper, show that there was no correlation between the students' *ATAR* and their spatial performance upon entering university to study *architecture.* Because university entrants into the programmes studied were "high achievers" at school, this meant that the participants were clustered around the three points at the high end of the ATAR scale as opposed to being spread across the entire ATAR range, making it difficult to establish a linear relationship that was a true reflection of the total population, but it is a true reflection for the cohorts of students who enter design courses of study such as Architecture.

It is of course possible that students with high ATAR scores had done subjects at school with little need for extended spatial ability, while other students did subjects that were spatial intensive. The amounts of spatial content students have done in subjects at school may also impact on the scores they go on to achieve in the 3DAT tests. A lower ATAR student who has done a suite of subjects with high spatial content, thus neutralising the correlation, may offset a high ATAR student with little previous academic experience in the spatial realm. The lack of a relationship between ATAR and spatial performance may have implications for the criteria currently used to gain entry into bachelor-level programmes of Architecture. Currently, a minimum ATAR is the sole entry requirement. Owing to the importance of spatial ability to academic success and job competency within design-based disciplines, an additional assessment of spatial ability prior to entering university may be warranted. It is not suggested that spatial ability be adopted as an additional entry requirement to programmes of study because of the complexity of organising tests for all potential applicants to a design programme. However, it is felt that benefits are better provided for students on entry to a programme, through testing all students entering a programme that utilises spatial ability. If the identification of students with poor spatial ability is followed by implementing an intervention such as a bridging course (Sorby, 2007) or tailored teaching methods (Akasah and Alias, 2010) to improve these skills, the outcome would be students who are more likely to achieve success. So for the future, there is still much to be known about spatial ability and its implication for design. The future for this research project is to focus on a number of issues. A priority is the need to better understand the way in which spatial ability develops in students studying design programmes. One aspect of this study has shown that students do improve during their first year of experience in design subjects, even though they may come into the programme with very different levels of spatial skill. The detail of what is happening, with this spatial ability improvement, is not understood, which of the array of the learning experiences improves student spatial ability. Understanding what we can do as curriculum designers to improve our students in this design competency is needed.

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