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Original Article

Spatial ability assessment: an aid to student selection for therapy radiography training

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Abstract

Therapy radiographers require the ability to perceive three-dimensional relationships, in order to position patients correctly for treatment. A test predicting this would therefore be useful during undergraduate selection. This study examines whether therapy radiographers have a greater spatial ability than the general population, and secondly the relationship between spatial and clinical ability.

A correlation design utilised 54 therapy radiographers. Each subject undertook 3 tests: 2 spatial ability tests; WAIS block test (WBT) and Lego block test (LBT), and a clinical set-up (CS). Results indicate that therapy radiographers have a significant higher level of spatial ability, $p < 0.001$, than the general population in the 25–34 year age group. Pearsons correlation of WBT with LBT ($r = 0.56$, $p < 0.0005$) demonstrated concurrent validity of the new LBT.

The results suggest therapy radiographers have a higher degree of spatial ability than the general population. A test of spatial ability would therefore be of use to determine potential clinical competency during undergraduate selection. Whilst a potential useful instrument has been identified further research needs to be undertaken in this area as spatial ability is just one factor needed for clinical competence.

Keywords

Clinical competency; spatial ability; student selection; WAIS block test

BACKGROUND

The ability to relate two-dimensional data into a three-dimensional image is considered a necessity for certain occupations such as pilots, air traffic controllers,[1] and surgeons.[2] A review of the literature indicates that some individuals have an aptitude superior to others in visualizing three-dimensional spatial relationships.[2–4] Suitable candidates for recruitment to these professions would be aided if employers were able to determine a candidates ability to perceive three-dimensional relationships. The literature suggests that manual dexterity is a trainable ability, while spatial ability skills remain stable over time,[5] indicating it is an inherent ability. This fact serves to strengthen the argument for the introduction of such a screening tool. To date no research is available to establish or refute this suggestion for therapy radiographers. The authors suggest that as a professional group therapy radiographers require this perceptual ability, for example to translate two-dimensional data from a computer plan to a three-dimensional patient.

This study therefore aims to: determine if therapy radiographers have a greater level of spatial ability than the normal population; to establish the concurrent validity of a new spatial ability test, and to investigate the link between psychometric tests for spatial ability and a clinical competence test.

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METHOD

Fifty-four therapy radiographers, age range 18–54 years and clinical experience ranging from 1–31 years (mean experience 9.3 years), were recruited to the study. The sample was comprised of volunteers from students and staff at Clatterbridge Centre for Oncology (CCO), Merseyside, and the Department of Radiotherapy at the University of Liverpool.

The test battery consisted of the WAIS block test (WBT),[6] Lego block test (LBT), and a clinical set-up (CS).

The WBT is one of a series of tests forming the WAIS-R test battery,[6] and is recognized as a test of two-dimensional spatial ability.[6,7] The LBT was based upon a test described by Smoker et al.,[3] to evaluate the ability of subjects to form three-dimensional mental rotations from two-dimensional images. The CS required a single field to be applied to a plaster head using an orthovoltage treatment machine.

PROCEDURE

The study was conducted at CCO. As a result of a pilot study it was anticipated that approximately 40 minutes would be sufficient time for each subject to complete the 3 tests. A mutually convenient time for each subject was established.

The WBT and LBT were performed at the desk outside a radiotherapy treatment room (orthovoltage), with the CS taking place inside the room. This location was chosen as it is on the periphery of the main department, thus minimising interruptions.

A short overview of all 3 tests was given to the subjects before the tests commenced. It was emphasised at this point that if they did not wish to carry on with the study now or at any point during the tests, they were able to leave. The subjects were assured that their data would be treated confidentially. The order in which the tests were given remained constant to minimise the possibility of knowledge gained from one completed test, providing an unfair advantage on subsequent tests.

The first test given was the WBT. This comprised of 9 identical wooden cubes, coloured white on two sides, red on two sides, and red/white on two sides. An accompanying booklet contained 9 cards, each with a different printed design. Each subject was shown a picture card and asked to form the same pattern with the blocks. All 9 designs were completed by each subject. It was explained that the designs need to be completed in the shortest time possible, although accuracy should not be jeopardised for speed. The completion time was recorded for each test. These times were then converted to a score, which was then corrected for age, using the tables supplied with the WAIS-R.[6]

The LBT was then completed. This comprised of 4 subtests, subtest 1 was demonstrated to all subjects. Each subtest required a structure to be built, from a given plan, out of Lego blocks. The plan is a schematic representation of the structure as viewed from the top and each of the four sides (Fig. 1). The subtests were designed to become increasingly more complex. This was achieved by using blocks of two different colours and increasing the number of blocks, including more blocks than required to complete the structure, and finally by adding a third colour of block as described by Smoker et al.[3]

- Subtest 1: 5 blocks of 2 colours, with the exact number of blocks,
- Subset 2: 6 blocks of 2 colours, again with the exact number of blocks,
- Subset 3: 6 blocks of 2 colours, with 2 extra blocks one of each colour added as a distraction,
- Subtest 4: 8 blocks of 3 colours, with 3 extra blocks one of each colour, added as a distraction.

The object of the test was to assemble the blocks in to a structure, to match the diagram, as quickly as possible. The time taken for the successful completion of each subtest was recorded using a digital stopwatch.

A scoring scheme was devised (Table 1) based on the WAIS[6] block test. Time limits for each subtest were set to prevent subjects continuing indefinitely. The time limits were derived from the longest time for successful completion in the pilot test. Subtest 1 and 2 was set at five minutes, while subtest 3 and 4 was ten minutes. Concurrent

Table 1. Lego block scoring system

		POINTS WITH TIME BONUS					
DESIGN	TIME LIMIT	0	1	2	3	4	5
1 & 2	5’	>5’	3’1”–5’	1’1”–3’	31”–60”	<30”	–
3 & 4	10’	>10’	7’1”–10’	4’1”–7’	3’1”–4’	2’1”–3’	<2’

Maximum score from all 4 subtests = 18 points

Figure 1. Lego block sub tests

validity was confirmed via a correlation with the WBT (r = 0.57, p <0.0005).

The CS required a single direct field to be applied to a plaster head, necessitating the use of skin apposition. The treatment machine and technique chosen were ones that were not in everyday use, thus ensuring all individuals would be relatively unfamiliar with the set-up. The principles of the selected technique were familiar to everyone, although the equipment was not, as it is rarely in clinical use. The machine's controls were demonstrated to the subjects, after which they were allowed 2 minutes familiarisation. It was envisaged that by using the same radiotherapy treatment machine and a plaster model, possible variations between subjects would be minimized. The procedure was carried out using a Siemens (Stabilipan 2) orthovoltage treatment machine.

Skin apposition requires the applicator of the treatment machine be aligned parallel to the skin surface that it is brought to rest upon. The set-up is completed when the applicator is brought to rest within the defined treatment area on the model. There should be no areas of stand off, i.e. the applicator surface should be flat on the model's surface. This was scored by the length of time taken to complete the task. This technique minimised subjectivity, as the set-up is either correct or incorrect.

Analysis

Descriptive statistics were undertaken on each of the three tests, these included mean, mode, standard deviation and frequency distributions.

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A two sample unrelated *t* test was conducted on mean WAIS block scores for the normal population[6] and the therapy radiographers scores. A chi-squared test was conducted on CS and years of clinical experience.

Correlations using Pearsons product moment correlation (PPMC), between the WBT and the LBT; CS and WBT, the CS with LBT and WBT, LBT with clinical experience were also undertaken. Statistical significance for all the tests was set at $p < 0.05$.

Statistical packages used for data analysis were Microsoft Excel version 5 and Lotus 123 release 1.0.

RESULTS

The study group comprised of 1 male and 53 female therapy radiographers . The age distribution ranged from 18–54 years with the majority of the sample being in the age range 25–34 (Table 2). The age ranges used followed those of the WAIS-R test battery,[6] thereby allowing comparisons to be made. The groups clinical experience, calculated to include time spent as a student, ranged from 1 year to 31 years, mean 9.3 years (SD = 6.47).

WBT scaled scores for all 9 block designs after age correction, for the study population ranged from 7 to 18 (maximum potential score for this test was 19). The mean total score for all designs was 12.2 (SD = 2.34), with a modal score of 12. An unrelated two sample *t* test was used to compare the study population's scores with that of the normal population (derived from WAIS-R[6]). Data for age groups 25–34 and 35–44 were available for comparative purposes. Therapy radiographers were significantly more competent within these age ranges (Table 3). Comparisons between the remaining age categories were not undertaken, as normative data was not available for all age groups for WAIS-R sub-scales. Furthermore, not all age-bands provided sufficient numbers for a meaningful analysis (Table 2).

The mean total score for all 4 subtests of the LBT was 4.96 (SD = 3.37), with a modal score of 5. The total scores achieved by the study group ranged from 0 to 16 (maximum potential score for this test was 18, higher score = faster completion time). The scores for the individual subtests varied markedly. Test 1 was found to be the easiest with 44 subjects successfully completing the design within the specified time, with 4 subjects giving up. Test 3 was found to be the most difficult with 18 subjects giving up, and a further 17 running out of time. Table 4 provides subtest results.

All 54 subjects successfully completed the CS. The time taken to complete this exercise ranged from 51 seconds to 18 minutes 24 seconds. The mean set-up time was 3.6 minutes (SD = 2.74). Level of clinical experience was significantly related to CS (chi-square, 9.94, DF, 54, $p < 0.04$), as clinical experience increased, clinical set up time decreased.

A non significant correlation was observed between spatial ability and clinical experience ($r = 0.61$, $p > 0.06$). A positive correlation was observed between the WBT and LBT, $r = 0.5701$, $p < 0.0005$, indicating concurrent validity. Low correlation's between WBT / LBT and the CS were observed ($r = 0.1277$, $p > 0.1$ and $r = 0.2296$, $p > 0.1$).

DISCUSSION

The WBT indicates CCO therapy radiographers, aged between 25- 44 years, have a greater level of spatial ability than the normal population.

Table 2. Age distribution of sample population

AGE RANGE (YEARS)	NUMBER PER GROUP
18–19	3
20–24	11
25–34	25
35–44	12
45–54	3
55–64	0
	n = 54

Table 3. WBT scores

AGE (YEARS)	MEAN WBT SCORES NORMAL POPULATION	THERAPY RADIOGRAPHERS	TWO SAMPLE *T* TEST
25–34	10.1 (SD=3.1; n=71)	12.4 (SD=2.2; n=25)	t=3.4379; p<0.001
35–44	9.9 (SD=3.3; n=72)	12.8 (SD=2.3; n=12)	t=2.923; p<0.01
45–54	8.2 (SD=2.3; n=48)	10.3 (SD=1.3; n=3)	

Table 4. LBT subtest data

	LEGO TEST 1	LEGO TEST 2	LEGO TEST 3	LEGO TEST 4
Completion time range (mins, sec)	16s – 4m 4s	45s – 4m 58s	2m 14s – 9m 15s	1m 56s – 9m 59s
Mean completion time (mins, sec) (SD)	1.02 (1.05)	0.59 (1.39)	1.58 (2.59)	3.08 (2.56)
Number completed	44	20	19	34
Number who ran out of time	6	27	17	12
Number who gave up	4	7	18	8
Range of scores	0–4	0–3	0–4	0–5
Mean score (SD)	2.06 (1.28)	0.43 (0.74)	0.72 (1.1)	1.48 (1.42)

Furthermore, clinical experience was related to CS, it was not, however, related to spatial ability. This is in agreement with the literature,[5] in that spatial ability appears to be an inherent trait and can not be learnt.

A review of the literature indicates that research into spatial ability levels for other professions allied to medicine has not been undertaken. It would be interesting to determine if significant differences in spatial ability exist between various health care professions. It is possible that candidates interested in becoming therapy radiographers are self selecting, as individuals with greater spatial ability may look for a job involving such skills. However, this is unlikely, as at the application stage they may not be aware that this skill is beneficial.

It was anticipated that therapy radiographers would not find the LBT too difficult, as they would adapt clinical skills, for example viewing orthogonal radiographs. It is apparent from the results that certain assumptions made while designing the LBT were not fully considered. The LBT diagrams were new to all subjects thus they were unable to relate the structure to anything they had seen before. Relating two radiographic views of the same body structure involves clinical and academic knowledge, allowing radiographers to anticipate the structures likely to be seen, before looking at the image. The LBT consisted of abstract shapes. With practice individual scores may well increase due to increased knowledge and understanding of what is required during the test.

The LBT subtest scores varied considerably. Subtest 1 was completed by the majority of subjects, with 10 subjects failing to complete (10/54). Subtest 1 was demonstrated to all subjects prior to test phase. It was found that if the top view was assembled first, followed by the sides, this approach was adopted by the majority. However, if the demonstration commenced with the side view being constructed this method was replicated by the majority of subjects. This implies that subjects were trying to reproduce the demonstration rather than working the structure out from the schematic drawing. Such an explanation would rationalize why there was a lower success rate on subtests 2, 3 and 4. The subjects who were successful in completing the structures used the plan view in conjunction with an elevation view.

Subtest 3 designed by Smoker et al.,[3] proved to be the most difficult structure to complete, as was the case in Smoker's study. It is possible that subjects who had been unsuccessful on the previous tests were discouraged, accounting for why 18 subjects gave up. The tests were designed to become progressively harder. Subtest 4, however, was successfully completed by more subjects than the previous two tests. This test included the use of three colours, potentially making the block placements easier to determine than in previous tests, leading to the higher success rate. Further research with variation in the number of colours per test will provide more information on test complexity.

The significant correlation of LBT with WBT, indicated the LBT is valid as a measure of spatial ability. Further research needs to be undertaken to develop this test and provide normative data. The potential for including spatial ability instruments in the selection of individuals into professions where spatial ability is a distinct advantage is currently being assessed by the authors.

Variation in CS times was recorded between subjects. CS results were divided into three equal groups according to times (Table 5). The longest CS time of 18 minutes 24 seconds (group 3) was recorded by a student, and should be seen in isolation as the previous recorded time was 10 minutes 22 seconds. Group 3 which contained the longest times included 64% of participating students. The student's longer set-up times could be partly due to their clinical tutor conducting the tests. The students may have felt intimidated by being observed by their supervisor and hence have taken longer, rather than differing in ability from the staff. This potential problem was recognised during recruitment and it was stressed to the students that they did not have to participate if they did not wish to. Out of thirteen students, eight volunteered to participate. Group 1, the fastest set up times contained 61% of subjects who had the greatest level of clinical experience.

Successful completion of CS occurred when the applicator surface was parallel and touching the surface of the model. This end point can correctly be achieved by more than one set-up approach. Five individuals (5/54) rotated the treatment bed through 90 degrees. The bed was then in line rather than perpendicular to the treatment machine. The head of the machine was then rotated laterally in order to achieve skin apposition. The individuals that completed the task in this way, achieved the five fastest set-up times. At the time of the study two of these subjects were treating with electrons. An electron treatment set up requires the use of skin apposition. The two subjects were using this technique daily on a different machine, giving them a possible advantage, however it must be noted that some of the subjects who did not approached the task in this way were also working with electrons.

Forty-nine subjects (49/54) made no attempt to alter the rotation of the bed from its initial setting. To complete the exercise it was therefore necessary to rotate the head of the machine anteriorly, and the applicator laterally. To achieve skin apposition this way, more parts of the machinery were required to be rotated, giving a corresponding longer set-up time.

Table 5. CS times

Group 1 (n=18)	51 secs – 2 m 42 secs	SD=0.62
Group 2 (n=18)	2 m 45 secs – 3 m 48 secs	SD=0.38
Group 3 (n=18)	4 m 6 secs – 18 m 24 secs	SD=3.44

The significant chi-square result ($p < 0.04$) suggests that the more experienced the subject the faster their CS time. The students lack of experience in the clinical setting may partly explain their longer set-up times. Experience provides a perception of confidence, and this can increase proficiency and speed. It is hoped to perform a retest on student participants in the future to monitor the effects of experience. A literature search found no papers examining therapy radiographers' clinical ability, allowing no comparison to be made with these findings. Similar studies undertaken by surgeons[8,9] compared clinical competence with spatial ability and found the relationship between the two was significant. It must be noted however that objective assessments of clinical ability are difficult to measure in medicine as the variables change, for example it may be the same procedure but the patient will differ and hence different problems may by experienced by the student. In this study, a relationship between clinical and spatial ability was not identified. This would suggest that spatial ability is innate and cannot be improved upon with experience. This ability however is an important skill, worthy of identification at an early stage in the selection or training process for candidates to disciplines where spatial ability can be considered a necessary element of the job skill mix.

CONCLUSION

The results of this study are comparable to research with other disciplines such as surgery,[2,5,10] dentistry,[11,12] and radiology.[3,13] It is suggested that psychometric testing does have a place in determining clinical potential. Within the NHS efficiency is necessary in order to maintain low waiting times. Efficient, competent practitioners are obviously key elements in this possess. Clinical competence however is composed of numerous equally important facets such as interpersonal skills, and technical ability. A psychometric test of clinical ability could therefore be used in conjunction with the traditional methods to aid selection, rather than as a replacement. Further research is required in this area to expand upon test selection procedures for radiographers and other relevant health professionals.

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