'Sorry, I meant the patient's left side': impact of distraction on left–right discrimination

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CONTEXT Medical students can have difficulty in distinguishing left from right. Many infamous medical errors have occurred when a procedure has been performed on the wrong side, such as in the removal of the wrong kidney. Clinicians encounter many distractions during their work. There is limited information on how these affect performance.

OBJECTIVES Using a neuropsychological paradigm, we aim to elucidate the impacts of different types of distraction on left–right (LR) discrimination ability.

METHODS Medical students were recruited to a study with four arms: (i) control arm (no distraction); (ii) auditory distraction arm (continuous ambient ward noise); (iii) cognitive distraction arm (interruptions with clinical cognitive tasks), and (iv) auditory and cognitive distraction arm. Participants' LR discrimination ability was measured using the validated Bergen Left–Right Discrimination Test (BLRDT). Multivariate analysis of variance was used to analyse the impacts of the different forms of distraction on participants' performance on the BLRDT. Additional analyses looked at effects of demographics on performance and correlated participants' self-perceived LR discrimination ability and their actual performance.

RESULTS A total of 234 students were recruited. Cognitive distraction had a greater negative impact on BLRDT performance than auditory distraction. Combined auditory and cognitive distraction had a negative impact on performance, but only in the most difficult LR task was this negative impact found to be significantly greater than that of cognitive distraction alone. There was a significant medium-sized correlation between perceived LR discrimination ability and actual overall BLRDT performance.

CONCLUSIONS Distraction has a significant impact on performance and multifaceted approaches are required to reduce LR errors. Educationally, greater emphasis on the linking of theory and clinical application is required to support patient safety and human factor training in medical school curricula. Distraction has the potential to impair an individual's ability to make accurate LR decisions and students should be trained from undergraduate level to be mindful of this.

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INTRODUCTION

Early in medical degree curricula, the importance of correct spatial orientation is emphasised and taught to medical students. The ability to distinguish anterior from posterior, and superior from inferior is vital if health care professionals are to accurately describe and potentially target a wide range of treatments. However, correctly distinguishing left from right is assumed to be an inherent skill that we all use correctly on a daily basis. This is not the case. A significant proportion of our population has difficulty in distinguishing left from right.[1–4] Medical students do not escape this trend, and female students and those students aspiring to become general practitioners or psychiatrists demonstrate the greatest difficulty.[5]

Confusing a patient's right side with his or her left has the potential to cause a serious adverse event and devastating consequences for the patient. Some of the most infamous errors in medicine have occurred when wrong-sided decisions have been made, such as in wrong-sided craniotomy, surgery on the wrong eye, and removal of the wrong limb, lung, kidney or testicle.[6–10] Such major left–right (LR) errors may represent only the tip of the iceberg; little is known about the frequency of more minor LR errors such as those of ordering a wrong-sided radiological image or applying therapy to the wrong side of the body.[6,7] Despite the attempts of the National Patient Safety Agency, the Joint Commission and other organisations, wrong-sided errors continue to occur.[10–12] Systems that use protocols such as 'time out' and checklists attempt to mitigate such LR errors. However, these 'never events' continue to take place.[10–12] Although such errors are frequently attributed to system failures, individual human error is considered to be a significant contributory factor and a root cause in many cases.[6] Error is considered to be an inherent characteristic of human behaviour.[13] Medical students with LR confusion appear to be aware of their own difficulties and attempt to develop compensatory mechanisms, such as by relating their left or right side to a number of features including physical activity (e.g. the hand they strum a guitar with) or an accessory feature (e.g. a wedding ring or wrist watch).[5] Generally, individuals who use these techniques still have difficulty in distinguishing left from right.[5]

Clinical competence is nested in a wide range of situational and contextual factors. When making LR decisions in the workplace, health care professionals encounter many distractions.[14–17] Distractions can arise from many sources and include verbal interruptions by colleagues (i.e. cognitive distractors), environmental noise and the sounds of electronic pagers or telephones (i.e. auditory distractors). Disturbances are known to contribute to other types of error, such as medication error.[18,19] However, it is unclear how distraction impacts upon health care professionals' LR discrimination ability.

Left–right discrimination is a complex process involving several higher functions, such as the ability to integrate somaesthetic and visual information, receptive and expressive language function, visuospatial function when mentally rotating images, and memory in retaining instructions related to tasks.[4,20] One of the most widely accepted models of attentional and memory processes is the multi-component model of working memory.[21,22] Working memory is considered to be used in tasks that require the integration of new stimuli with long-term memory, and the maintenance of information for complex tasks. Importantly, working memory is considered to be of limited capacity. Left–right discrimination can be assumed to impose some demand on the working memory system.[20,23] In a situation in which an individual is required to divide his or her attention between the performance of a mentally demanding task (e.g. LR discrimination) and a response to external stimuli (e.g. distraction), this individual might hypothetically struggle to successfully complete both tasks, particularly when the secondary task is also taxing his or her working memory system.

To date no studies have investigated the impact of distraction on an individual's LR discrimination ability. Given how important it is that health care professionals make correct LR decisions and that training begins at an undergraduate level, we aimed to assess the impacts of different distraction modalities (i.e. cognitive and auditory) on LR discrimination ability in medical students. Secondary research objectives were to determine: (i) if there was any correlation between medical students' perceived and actual LR discrimination ability, and (ii) the impacts of demographic factors such as age, sex and handedness on medical students' LR discrimination.

METHODS

Study design

The study was observational in nature and involved the use of a validated psychometric tool to quantitatively assess LR discrimination ability.

Study setting, sample size and recruitment

The study was set in the Centre for Medical Education, Queen's University Belfast. The medical degree programme at this university follows a 5-year integrated curriculum model. In May 2012, Year 2 students attending a clinical skills course were invited to take part in the study (n = 269). At this stage of their training, students' studies mainly focused on the scientific foundation of clinical practice, with incremental patient contact in various clinical environments. One quarter of the year group (approximately 68 students) were expected to attend each of four randomly allocated clinical skills training afternoons. Ethical approval was obtained from the school's research ethics committee.

We aimed to recruit a minimum of 128 students in total (i.e. 32 subjects per each of the four arms of the study) to provide 80% power to detect a significant difference in the main effects in an analysis of variance (ANOVA) with an α-value of 0.05 and an assumed effect size of 0.06 (partial η^2).

Subject questionnaire

Consenting students were asked to complete an anonymised questionnaire capturing their sex, age and handedness (using the Edinburgh Handedness Inventory[24]). A self-rating questionnaire was used to ascertain subjects' perceived LR discrimination ability, which was recorded using a 78-mm visual analogue scale (0 = no problems, 78 = constant problems).[25]

Objective measurement of subjects' LR discrimination ability

The Bergen Left–Right Discrimination Test (BLRDT) was used to measure participants' LR discrimination ability and was administered according to the BLRDT protocol.[4] In this psychometric test, subjects are presented with a series of stick figures in which a white head indicates that the figure is being observed from the front and a black head indicates that the figure is being observed from behind.

Each of the stick figures' hands is represented by a circle. Below each figure is either of the letters L (left) and R (right). Subjects are asked to place an X in the appropriate circle as indicated by the letter L or R below the figure. The BLRDT is administered in a timed fashion and consists of three subsections (each to be completed in 90 seconds). Each subsection contains 48 stick figures to give a total score of 0–144. In the first subsection, all of the figures are observed from the back; in the second, all are observed from the front, and in the third, figures are observed in a mixed fashion. Subsections were administered in a counterbalanced sequence to account for order effects.

Deployment of distraction stimuli

The study had four arms. Participants in arm 1 (control) performed the BLRDT without distraction in a quiet lecture theatre. In arm 2, participants were asked to complete the BLRDT in the same context as in arm 1, but with the addition of auditory distraction in the form of a pre-recorded sample of typical clinical ward noise, which contained background human voices, monitor alarms and telephones (played at 70 dB). In arm 3, participants were asked to complete the BLRDT as in arm 1, but with the addition of cognitive distraction in the form of a series of three sets of five verbal statements (short pieces of clinically relevant information), each delivered in a timed fashion throughout the course of the BLRDT. Sample statements are shown in Appendix 1; a fuller version is available in Appendix S1. After each subsection, subjects were asked to pause and to write down answers to five questions, one pertaining to each of the five distraction statements (scored as either 'correct' or 'incorrect'). In arm 4, the BLRDT was administered with the auditory distraction utilised in arm 2 and the cognitive distraction used in arm 3 (simultaneously).

Data analysis

The primary analysis examined the differences in scores on each subsection of the BLRDT in each arm of the study. This was achieved using between-groups multivariate ANOVA (MANOVA), in which the factor was study arm (control, auditory distraction only, cognitive distraction only, and cognitive and auditory distraction) and the three dependent variables were BLRDT subsection (facing away, facing forward, mixed). *Post hoc* Tukey's tests were used to make pairwise comparisons among the study arms for each BLRDT subsection. Additional analyses included ANOVAs looking at the effects of age, sex and handedness on performance in the BLRDT with and without distraction. For the ANOVA models, the effect size used was partial η^2; values of ≥ 0.06 and < 0.14 were considered to represent medium effect sizes, and values of ≥ 0.14 were considered to indicate large effect sizes.[26] Pearson's correlation coefficient was used to examine the association between participants' perceived LR discrimination ability and their performance in the BLRDT. All analyses were conducted using IBM SPSS Statistics for Windows Version 21.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Response rate and participant demographics

A total of 234 of 269 students participated in the study (recruitment rate: 87.0%). Recruitment exceeded the 32 subjects per arm required to achieve power. Of the participants who provided data on their sex, 55.2% (122/221) were female and 44.8% (99/221) were male. Additional data showed that 88.8% (207/233) of participants were right-handed and 11.2% (26/233) were left-handed. The majority (62.8%; 145/231) of participants were aged 18–20 years; 37.2% (86/231) were aged 21 years and over. Table 1 summarises the age, sex and handedness of participants in each of the study arms.

Impact of different modalities of distraction on participants' BLRDT performance

A statistically significant difference among the four arms of the study was found in overall BLRDT performance ($F_{(9,690)} = 5.97$, $p < 0.001$, partial $\eta^2 = 0.07$). Table 2 summarises the results for each subsection of the BLRDT and shows that significant differences were found among the four arms of the study for each subsection of the BLRDT. *Post hoc* tests indicate that performances in the cognitive-only, and cognitive and audio distraction arms differed significantly from that in the control arm in each subsection of the BLRDT. Performance in the audio-only distraction arm did not differ significantly from that in the control arm in any of the BLRDT subsections.

In addition, the *post hoc* tests showed that performances in the cognitive-only, and cognitive and audio combined distraction arms did not differ significantly on the BLRDT facing away and facing forward subsections. On the BLRDT mixed subsection, performance in the cognitive and audio distraction arm was significantly poorer than that in the cognitive-only distraction arm.

Impact of handedness, sex and age on participants' BLRDT performance

The separate potential moderating effects of handedness, age and sex on the relationship between distraction type and overall BLRDT performance were not found to be significant. Both sex and age were found to be significant additional covariates, in that,

Table 1 Participant sex and handedness in each of the study arms

	Arm 1 No distraction	Arm 2 Auditory distraction	Arm 3 Cognitive distraction	Arm 4 Auditory and cognitive distraction
Sex				
Female (%)	69.6	52.5	47.3	51.0
Male (%)	30.4	47.5	52.7	49.0
Handedness (%)				
Left	15.0	6.3	10.5	13.5
Right	85.0	93.8	89.5	86.5
Age, years (%)				
18–20	63.9	57.8	61.4	65.4
≥ 21	36.1	42.2	38.6	34.6

Table 2 Mean correct responses on the Bergen Left–Right Discrimination Test (BLRDT) based on figure orientation

	Scores, mean ± SD*		
	BLRDT figures facing away	BLRDT figures facing forward	BLRDT figures in mixed orientation
Arm 1 (control) (n = 61)	43.6 ± 7.7	39.6 ± 9.8	36.9 ± 8.5
Arm 2 (auditory distraction) (n = 64)	42.0 ± 6.5	38.6 ± 8.7	34.7 ± 9.4
Arm 3 (cognitive distraction) (n = 57)	37.4 ± 7.5†	35.0 ± 10.3†	32.6 ± 8.2†
Arm 4 (mixed auditory and cognitive) (n = 52)	35.0 ± 8.4†	31.1 ± 10.1†	27.3 ± 7.8†
	$F_{(3,230)} = 16.24$	$F_{(3,230)} = 8.98$	$F_{(3,230)} = 12.63$
	$p < 0.001$	$p < 0.001$	$p < 0.001$
	$\eta^2 = 0.18$	$\eta^2 = 0.11$	$\eta^2 = 0.14$

SD, standard deviation.
* BLRDT scale of 0–48 for each subsection.
† Statistically significant difference from control group (p < 0.05).

in general, males outperformed females ($F_{(3,211)} = 3.53$, $p < 0.05$, partial $\eta^2 = 0.05$) and the 18–20-year-old age group outperformed the ≥ 21-year-olds ($F_{(3,224)} = 3.30$, $p < 0.05$, partial $\eta^2 = 0.04$) in overall BLRDT performance.

Analysis of perceived LR discrimination ability and BLRDT performance

Pearson's correlation coefficient (r) was calculated to assess the correlation between baseline perceived LR discrimination ability and actual performance on the BLRDT. There was a significant medium-sized correlation between perceived LR discrimination ability and actual overall performance on the BLRDT ($r = -0.39$, $p < 0.001$, two-tailed).

DISCUSSION

The results of this study suggest that cognitive distraction, more than auditory distraction, has an impact on medical students' ability to discriminate left from right.

Background auditory distraction, on its own, appears to have little impact on medical students' overall BLRDT performance. Pure cognitive distraction demonstrated a significant negative effect on medical students' performance on the BLRDT throughout all subsections. There is no previous literature addressing the impact of cognitive distraction on performance on the BLRDT; however, literature relating to the effects of distraction in the anaesthesia and surgical environments highlights the frequency of distraction in the clinical environment and thus the potential impact upon patient safety.[27–30] Investigators looking at the impact of different modalities of distraction in the urological theatre environment found verbal communication between staff proved more distracting than simple background noise, such as the sounds of pagers and ringing telephones.[27] This supports our finding that direct verbal communication with subjects is more distracting than exposure to background noise.

Urologists are exposed to a lot of distraction during their operative work; it has been suggested that as they increase in experience, surgeons may develop the ability to filter out distracting stimuli, albeit incompletely as many still report distraction to represent a major stressor in the operative environment.[28] This hypothesis has been tested and the process whereby surgeons develop the ability to 'ignore' distractions referred to as 'technical automatisation'.[31] In a simulated surgical environment, Hsu *et al.*[31]developed a laparoscopic paradigm in which a cohort of experienced surgeons and a cohort of novices were trained to transfer pegs in a laparoscopic simulator. Before any distraction was implemented, both cohorts were required to demonstrate consistent proficiency in the peg transfer task. When this phase was completed, both cohorts were exposed to cognitive distraction according to a protocol in which they were asked to complete the simulated laparoscopic task whilst completing mental arithmetic problems. The study demonstrated that experienced surgeons were able to complete the simulated laparoscopic task in a technically proficient way despite distraction, with no drop in peg transfer score, and, similarly, were able to complete the mental arithmetic task accurately.[31] The novice cohort, despite showing no significant drop in peg transfer score with cognitive distraction, demonstrated a significant negative impact on performance in the arithmetic task in terms of the percentage of correct responses and numbers of questions attempted, suggesting that it is possible that doctors can be trained to adapt to cognitive distraction by developing a degree of technical automatisation in the tasks they are completing.[31] This suggests that experience and repeated exposure to distracting stimuli are key to developing a more 'automatic' approach to tasks. Thus, these are potential areas to be developed in the undergraduate medical curriculum to improve patient safety.

The BLRDT is made up of three subsections, each of which is made more difficult than its predecessor by the orientation of the figures. This is evident in the trend in scores, which show a deterioration in performance across the three subsections regardless of the study condition. The only other study looking at performance on the BLRDT in this population demonstrated a similar pattern of performance.[5] On the first two subsections of the BLRDT, students in the combined cognitive and auditory distraction condition did not perform significantly worse than students in the cognitive-only distraction condition. However, in the third and most difficult subsection of the BLRDT, the combined auditory and cognitive distraction resulted in poorer performance on the BLRDT than cognitive distraction alone. This suggests that, when faced with a cognitively complex task, although auditory distraction does not have a significant impact, it can have a significant additive effect when cognitive distraction is also present. It may be that people reach a ceiling in terms of their cognitive load capacity when managing a cognitively complex task in the face of cognitive distraction. In this circumstance, an otherwise relatively innocuous distraction can become an added burden that further affects performance.

Medical students' perceived and actual LR discrimination ability

Results from our study indicate that medical students' perceived and actual LR discrimination ability correlated only at a moderate level, suggesting that students' perceptions of their ability are, in general, inaccurate. The pattern of results suggests that students both over- and underestimated their LR discrimination ability. This is an area of concern, particularly in situations in which students do not perceive a problem with their discrimination ability. Therefore, a simple but important task for medical educators may be to provide students with opportunities to test their LR discrimination abilities. Both medical students and practising doctors must accurately and continually appraise their own abilities. They need to identify areas of practice that require further development and training, not only with reference to technical skills, but also in terms of human factor skills such as LR discrimination.

Impact of demographic factors and handedness on LR discrimination ability

This study also sought to identify whether there was a sex difference in LR discrimination ability in medical students and if this modified in any way the impact of different modalities of distraction on their performance on the BLRDT. Our results suggest that there was a significant effect of sex on overall performance on the BLRDT and that this effect approached a medium effect size whereby males outperformed females. These results corroborate the findings of those who have demonstrated experimentally a consistent effect of sex on LR discrimination ability.[4,32–35] With regard to the mechanism by which males outperform females in tasks of LR discrimination, the consensus in the literature would appear to support the theory that males demonstrate a greater degree of functional hemispheric asymmetry and superiority of visuospatial function.[32,35] Handedness has no overall effect on LR discrimination ability.[32,33] Our study supports this conclusion as no significant effect of handedness was seen in medical students and nor did it modify the effects of different distraction modalities.

Limitations of the study

A key strength of this study is its attempt to explore an area that has been relatively under-investigated to date. However, the findings of this study must be considered within its limitations. The use of a single cohort of medical students at a single centre is a limitation and the results may not be fully generalisable to other institutions. To control for cognitive speed, the BLRDT was performed in a timed fashion. If there was no time limit for the completion of the test, participants would be able to take time during the test to develop novel strategies with which to overcome the challenges of the task, thereby masking any underlying impairment of LR discrimination ability and reducing the sensitivity of the test. This strategy is also a potential limitation of the study because completing the BLRDT under the stress imposed by a time limit may itself impact negatively on performance. To control for confounding factors the study was not carried out in an ecologically valid setting (i.e. a working clinical ward). Nonetheless, the distractors used were based on real examples of commonly experienced clinical distractors. This study did not set out to investigate the effect of distraction on LR discrimination coupled to actual errors occurring in clinical practice, such as is theorised in Perrow's normal accident theory.[36]

Implications of this study and recommendations

Left–right discrimination represents a human factor patient safety issue that is pertinent in a wide range of clinical contexts. This study is the first to demonstrate that distraction has an impact on LR discrimination ability in medical students and thus suggests that a human factor of this type in health care can be negatively influenced by environmental factors such as noise and verbal distraction. Not only does this study demonstrate that distraction can negatively impact upon the performance of non-technical skills, such as LR discrimination, but it also shows that non-modifiable factors such as age and sex impact upon performance; these impacts should be taken into consideration when designing a non-technical skills curriculum. Furthermore, the study demonstrated that a significant proportion of medical students do not appear able to recognise their limitations in terms of LR discrimination ability.

The practice of medicine encompasses the integration of many complex and socially positioned skills, which are often subject to many different contextual stimuli that are invariably present in busy workplaces. Therefore, educational frameworks must consider the environment in which clinicians and medical students work, and the complex interplay between the individual and the environment. The aviation industry has demonstrated that non-technical skills cannot be acquired reliably in the workplace without specific training in crew resource management.[37] Medical education can learn from aviation training as it has in postgraduate training in anaesthesiology; there is no reason why training based on crew resource management protocols cannot begin in the undergraduate curriculum.[30,37] The operating theatre is but one example of an environment with potentially unlimited distractors, yet is the very place where important LR decisions are made, such as those pertaining to the removal of a paired organ or limb. Anaesthetists refer to the 'sterile cockpit concept', whereby the administration of an anaesthetic agent should be considered subject to a principle akin to the 'cockpit rule' for pilots.[38] The cockpit rule stipulates that pilots must refrain from all 'non-essential conversation and activity' during the critical phases of a flight.[38]

Medical schools should be proactive in helping students to identify proneness for making such non-technical skill errors. Perhaps students, at an early stage in their training, could be offered the opportunity to objectively assess their LR discrimination ability (e.g. by using an online version of the BLRDT). Faculty staff could then offer any student identified as challenged in making LR decisions measures to develop these skills and provide advice about coping strategies, particularly in the workplace. The introduction of teaching methods, such as high-fidelity clinical simulation, could offer students exposure to concepts such as situational awareness and the myriad of stimuli often encountered in the busy working environment. Interprofessional education programmes have an important role to play in emphasising the use of effective communication skills between health care professionals, and the potential impact of interruptions on an individual's performance.

In summary, LR discrimination is a contextual skill and, for many, a challenge. Multifaceted and strategic approaches are required to reduce the occurrence of LR errors. From an educational perspective, a greater emphasis on the application of theory and knowledge to clinical practice is required to support the focus on patient safety in medical school curricula. Non-technical issues, such as distraction, have the potential to impair an individual's ability to accurately make LR decisions. Training, starting at an undergraduate level, needs to make students mindful of the potential impact such distractions may have on their ability to make critical decisions. Their learning should also equip them with strategies with which to mitigate such error-provoking situations and to prevent the occurrence of potential adverse patient events.

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Appendix 1

Distraction statements

The statements below were delivered verbally to students during the cognitive distraction arms of the study (arms 3 and 4). Before the statements were verbalised, the following instructions were read out.

Whilst performing the Bergen Left–Right Discrimination Test, you will hear a number of verbal statements. We ask you to memorise these statements.

After the test, we will ask you to answer questions relevant to these statements. We ask you NOT to write the statements down. All paperwork will be collected after the exercise.

Sample statements

First section

Mr Frank Jones needs co-codamol 15/500 mg 2 every 4–6 hours when required written up.

Second section

When you are finished, can you administer Mrs Frances Tweedie's i.v. amoxicillin 500 mg?

Third section

Mrs Tweedie is due to go for a CT scan of the abdomen. The radiographer wants to know if she has been properly prepared for this?

Questions used to provoke cognitive distraction

First section

What dose of co-codamol did Mr Frank Jones need written up?

Second section

What drug did Mrs Frances Tweedie require administered?

Third section

What body area was being imaged (i.e. CT scan) in Mrs Tweedie?

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Distraction statements.

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