Use of inductive, problem-based clinical reasoning enhances diagnostic accuracy in final year veterinary students

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Abstract
Despite tremendous progression in the medical field, levels of diagnostic error remain unacceptably high. Cognitive failures in clinical reasoning are believed to be the major contributor to diagnostic error. There is evidence in the literature that teaching problem-based, inductive reasoning has the potential to improve clinical reasoning skills. In this study, 47 final-year veterinary medicine students at the Royal Veterinary College (RVC) were presented with a complex small animal medicine case. The participants were divided into two groups, one of which received a prioritised problem list in addition to the history, physical exam and diagnostic test results provided to both groups. The students' written approaches to the case were then analysed and assigned a diagnostic accuracy score (DAS) and an inductive reasoning score (IRS). The IRS was based on a series of pre-determined characteristics consistent with the inductive reasoning framework taught at the RVC. No significant difference was found between the DAS scores of each group, indicating that the provision of a prioritised problem list did not impact diagnostic accuracy. However, a significant positive correlation between the IRS and DAS was illustrated for both groups of students, indicating increased use of inductive reasoning enhances diagnostic accuracy. These results contribute to a body of research proposing that inductive, problem-based reasoning teaching delivered in an additive model, can enhance the clinical reasoning skills of students and reduce diagnostic error.

Key words
Clinical reasoning. Clinical approach. Diagnostic accuracy. Diagnostic error. Veterinary education. Pattern-recognition. Inductive reasoning. Problem-based reasoning. Problem-solving.

Introduction

Medical research demonstrates that 10-15% of clinical cases culminate in misdiagnosis.[1,2] Cognitive failures are a significant contributor to these levels.[3,4] Current psychological theory, supported by neuroanatomical research, states that human reasoning is a continuous interaction between two processing systems; a fast, intuitive system (Type 1) and a slow, reflective system (Type 2).[5–7]

In medical clinical reasoning, Type 1 processing has been referred to as 'pattern-recognition'- a cognitive function which relies on mental networks known as "illness scripts" embedded in long term memory.[8] This is a highly efficient, rapid process[9] which is accurate if the correct patterns are well encoded. As a result, it is essential for normal cognitive function in everyday life and is utilised in greater than 95% of our decision making.[10–12]

However, excessive reliance on pattern-recognition has been shown to decrease diagnostic accuracy[13,14] and some have particularly cautioned against its over-use among 'inadequately experienced' clinicians.[15]

Type 2 analytic processing commonly takes the form of either backward or forward (inductive) reasoning.[16] Backward or hypothetico-deductive reasoning involves the traditional scientific procedure of developing hypotheses and working backwards to test them.[17,18] However, clinically it has been suggested that this approach is often not viable, particularly in first-opinion practice, where a vast number of possible diagnoses can result in cognitive overload.[19,20]

Forward or inductive reasoning has the potential to provide a more manageable approach. More successful medical problem solvers tend to use a data-driven approach, starting with the problem and working forwards to the solution[32].

Regardless of type, analytic reasoning is not immune to error, predominantly due to the significant demands it places on limited short-term, working memory processes and the resultant speed limitations.[10,21,22] For these reasons, its use may not be appropriate in certain circumstances, for example the so called 'paralysis by analysis' situation in an emergency.[23] Type 2 reasoning is also susceptible to cognitive bias, particularly premature closure – the most common cause of diagnostic error.[10,24]

Scheme-inductive reasoning is a highly structured form of forward reasoning which has experimentally shown more accuracy than backward reasoning.[15,25] The Royal Veterinary College (RVC) has incorporated problem-based, inductive reasoning teaching into its clinical curriculum. This strategy has similarities with scheme-inductive frameworks and involves encouraging students to firstly identify specific problems in any presenting case and formulate a prioritised list of those problems.[26] They then work forward from that list defining and refining the problems, including the body systems and likely locations within those systems involved.[27] Ultimately the aim is to condense the problem to the point where a manageable list of differentials can be considered, appropriate diagnostic tests applied and the primary lesion defined.[28]

Researching the influence of a given clinical reasoning approach on diagnostic accuracy has thus-far been confined to human medicine.[29,30] Vinten et al.[31]

emphasised the lack of research into mechanisms of veterinary clinical reasoning and the uncertainty among veterinary educators as to the extent human medical research could be applied to their field.[26] These issues in conjunction with the many seemingly divergent views, mean that any decision regarding incorporation of clinical reasoning into veterinary curricula is a challenging one.[32]

This study examines the clinical approaches of final year veterinary medicine students at the RVC, with the aim of assessing the impact inductive reasoning has on diagnostic accuracy. The results from this study will be useful in making recommendations on teaching emphasis in the clinical reasoning arena. The hypotheses are (1) that providing a prioritised problem list improves diagnostic accuracy (based on the findings of Auclair[30] that presenting medical students with a formulated version of a complex case resulted in improved diagnostic accuracy) and 2) that use of an inductive reasoning schema positively affects diagnostic accuracy.

Materials and methods

Student recruitment and data collection

Final year veterinary medicine students from the RVC were recruited purposively. Students had received the same inductive reasoning teaching and were divided into two groups based on 4th year examination results to ensure that the mean and range of scores were comparable in both groups. They were presented with the case of a coughing dog with several co-morbidities which was based on a real clinical scenario (Appendix 1). Both groups received the history, physical exam and results of diagnostic procedures, including thoracic radiology, haematology, biochemistry and a trans-tracheal wash. Group one (G1: total 23 students) were additionally provided with a prioritised problem list, developed in concordance with Maddison et al's description.[28] Group 2 (G2: total 24 students) received no problem list. The students were then given one hour, under exam conditions, to provide a written assessment of the case concluding with differential diagnoses. The study received ethical approval from the RVC Clinical Research Ethical Review Board.

Analysis

The assessments were then analysed and each candidate was assigned two scores. Firstly, a diagnostic accuracy score (DAS) defined by the sum of their accurate differentials, minus their inaccurate ones. This was calculated blind to group allocation. Secondly, an inductive reasoning score (IRS) calculated by analysing their answers for a pre-determined list of characteristics associated with the inductive reasoning framework taught at the RVC (Table 1). This process was carried out blind to DAS and group allocation.

PLACE TABLE I HERE.

Table I: Table showing characteristics used to calculate the IRS[33].

The finalised data-set was transferred to Graphpad Prism 6, where two methods were used to statistically analyse the impact of inductive reasoning on diagnostic accuracy.

Firstly, the DAS and IRS of G1 was compared with that of G2, to assess whether significant differences existed. The D'Agostino & Pearson omnibus normality test confirmed a Gaussian distribution of the data. The mean DAS and IRS were then calculated for G1 and G2. An independent T-test was used to ascertain whether a significant difference existed ($p<0.05$=significant).

Secondly, the data were organised to enable analysis of the correlation between the independent IRS variable and the dependent DAS variable. This was carried out for G1 and G2 together, as well as independently. All the data-sets showed a Gaussian distribution according to the D'Agostino & Pearson omnibus normality test, so Pearson correlation coefficients were calculated ($p<0.05$=significant).

Results

Forty-seven students took part in the study, with two being removed after data collection due to incomplete 4th year examination records.

Method one analysis

Table 2 shows the results of the first method of analysis, comparing the DAS and IRS of G1 and G2 using an independent T-test. According to this test, there was no significant difference between the two groups of students with regards to their DAS and IRS.

PLACE TABLE II HERE.
Table II: Table showing the results of the T-test comparison of DAS and IRS, between G1 and G2.

Method two analysis

The second method of analysis assessed whether an increased IRS correlated with an increased DAS. Having found an insignificant difference between the DAS and IRS of the two groups in method one, the correlation between IRS and DAS was first assessed for all 47 students together. Figure 1 shows the scatter graph that results. The mean IRS for both groups was 5.77 and the mean DAS was -0.68. There was a significant, strong positive correlation between IRS and DAS (Pearson's correlation coefficient = + 0.6406; p=<0.0001).

PLACE FIGURE I HERE.
Figure I: A scatter plot showing the relationship between IRS and DAS for all 47 students.

Figure 2 shows the scatter graph that results when IRS is plotted against DAS for G1 only. There was a significant, strong positive correlation between IRS and DAS (Pearson's correlation coefficient = + 0.8248; p=<0.0001).

PLACE FIGURE II HERE.
Figure II: A scatter plot showing the relationship between IRS and DAS for G1

Figure 3 shows the scatter graph that results when IRS is plotted against DAS for G2 only. There was a significant, moderate positive correlation between IRS and DAS (Pearson's correlation coefficient = + 0.4939; p= 0.0142).

PLACE FIGURE III HERE.
Figure III: A scatter plot showing the relationship between IRS and DAS for G2

Discussion

In medical and veterinary education, efforts have been made to reduce cognitive failure in clinical reasoning through various instruction methods including problem-based learning (PBL) techniques and cognitive bias awareness teaching.[10,34] These strategies may have had some positive effects, however their efficacy at improving clinical reasoning and thus diagnostic accuracy appears to have been minimal.[10,35–38]

Implementation of inductive reasoning into clinical decision making teaching has the potential to succeed where others have failed.[15,39] Theoretically, inductive reasoning could simultaneously improve Type-1 pattern recognition accuracy, reduce analytical reasoning error and provide an efficient Type 2 cross-checking mechanism. Given the reliance of pattern recognition on script theory, its accuracy can be bolstered through the development of an increased number of better-encoded patterns; a recognised result of effective inductive reasoning.[32] The concept of Type 2 processing acting as a cross-checking mechanism has been appreciated for several years. As stated by Kahneman; 'recognize the signs that you are in a cognitive minefield, slow down, and ask for reinforcement from System 2'.[40(p.417)] Educating medical students about inductive reasoning could, therefore, encourage optimum use of both their Type 1 and Type 2 cognitive processing mechanisms.

In this study of the impact of inductive reasoning strategies on diagnostic accuracy, the first hypothesis 'that providing a prioritised problem list improves diagnostic accuracy' was rejected. Not only is the provision of a prioritised problem list not sufficient to achieve more accurate diagnoses but analysis also showed it had no significant effect on the frequency of inductive reasoning used by students. This outcome appears contrary to Auclair's[30] findings, that presenting medical students with a formulated version of a complex case resulted in improved diagnostic accuracy. The most likely reason for this discrepancy is that all the students in G2, who did not receive a prioritised problem list, composed a list themselves, with 18/24 students correctly identifying all ten problems. This is likely a result of the inductive reasoning teaching all participants in the study received during their clinical teaching at the RVC. This also explains why all students in the study utilised inductive reasoning to a greater or lesser extent in their case approaches.

Although all G2 participants formulated their own problem list, only 4/24 students further prioritised the list. This lack of comprehensive problem formulation by the majority of the group was not sufficient to impact their diagnostic accuracy. It may be that the act of constructing a problem list is important for initiating inductive reasoning and therefore providing students with the end-result is not beneficial. This is supported by feedback from participating students indicating that the presence of a formulated problem list 'distracted' them from approaching the case using the inductive logic they had been taught.

The failure to detect an impact on diagnostic outcomes following attempted experimental manipulation of reasoning strategies is not unprecedented. Norman states that most studies examining clinical reasoning using this method have yielded similar outcomes.[41]

The second hypothesis, ‘that use of an inductive reasoning schema positively affects diagnostic accuracy’ was proved. The results show a significant, positive correlation between the two variables for the entire study cohort, as well as G1 and G2 respectively. However, the correlation for G2 is weaker and less significant. One explanation for this finding is that G2 participants more frequently engaged in clinical reasoning techniques alternative to the inductive approach and thus more variables were impacting diagnostic accuracy. This increased use of alternative approaches could be a result of the fact that G2 were not provided with a prioritised problem list. Therefore, it is postulated that the provision of a prioritised problem list ‘streamlines’ inductive reasoning, encouraging students to adhere more closely to the problem-based framework.

The positive correlation between IRS and DAS supports research by Patel and Groen[42] showing that more successful problem solvers tend to use a forward reasoning approach. The present study also reinforces Coderre et al’s.[15] conclusion that scheme-inductive reasoning yields more accurate diagnoses than hypothetico-deductive reasoning. In addition, some of the characteristics considered markers of inductive reasoning in this study share similarities with the higher order concepts and semantic qualifiers described by Auclair[56] and Bordage.[60] As a result, this study corroborates their findings that increased use of these features improves diagnostic accuracy.

Conversely, an experimental study examining electrocardiogram (ECG) diagnosis by novices showed that increased accuracy was associated with a combined approach, initiated by backward reasoning.[44] One explanation for this alternative outcome could be the significant difference between the more superficial approach required for ECG diagnosis, compared with the complex medical reasoning required for the case used in this study. Elements of backward reasoning were incorporated into the approaches of some students in this study however it was not quantitatively examined and therefore its impact on diagnostic accuracy cannot be assessed. Previously, Norman et al.[45] had found that increased expertise amongst nephrologists did not correlate with either increased forward or backward reasoning. Any direct comparison between this conclusion and that of the present study is limited by the difference in study subjects; namely experts versus novices.

There are several possible explanations for the improved accuracy of the students utilising more inductive reasoning. Firstly, the use of pattern-recognition was difficult because this was both a novel and complex case for the inexperienced students it was presented to. Pattern-recognition provides solutions to problems solved in the past and thus consigned to the long-term memory as illness scripts.[46,47] For this reason, it has limited efficacy in solving new problems. In addition, intuitive approaches are inferior at breaking down complicated problems.[15,48] Studies have shown that when faced with complex problems, experts frequently do not employ pattern recognition but rather alternative techniques such as logical schema induction.[41,45] Students who attempted to pattern recognise without utilising analytical reasoning, despite the difficulties in this case, will have been more susceptible to a number of cognitive biases. The logical inductive framework appears to reduce the influence of these biases on decision-making.

Secondly, the methodology involved in inductive reasoning means it is a more effective analytical problem solving technique. For example, intrinsic to the inductive approach is clustering of individual data into meaningful relations.[20,49] This chunking of clinical facts has been associated with increased expertise.[45] In addition, inductive reasoning forces the clinician to comprehensively examine the data first and then work forwards – an approach which reduces the likelihood of missing important facts. Hypothetico-deductive reasoning approaches do not share these characteristics and have been described as weak methods of problem solving, being both inefficient and error-prone.[50,51] Therefore, students who utilised deductive, rather than inductive techniques will have found accurate diagnosis more difficult.

One of the expected outcomes of the current investigation is to contribute to decision-making in the veterinary education field. This study supports literature suggesting that inductive reasoning teaching should be incorporated into veterinary clinical curricula.[20,32]

Feedback from veterinary students indicates that effective clinical reasoning skills do not just develop as individuals progress through the course.[52] Rather, these attributes need to be nurtured and taught,[53] while allowing students to take responsibility for clinical decisions during their training.[31] In this regard, inductive reasoning teaching has the potential to succeed in improving the clinical reasoning development of students, where several other approaches have had minimal impact.[10,15,39] May has suggested that inductive reasoning ideas should be introduced to veterinary students earlier in the course, to help make the step from pre-clinical to clinical curricula easier.[32]

This study illustrates the benefits of employing inductive reasoning in one clinical case, however its positive impact is not limited to the short-term. Effective inductive reasoning has been shown to have long term impacts in improving pattern-recognition through the development of well-encoded scripts.[8,49] This is not an attribute of hypothetico-deductive reasoning.[38,54] Moreover, the inductive framework is one that can be adapted to many different presenting problems, providing a firm base for clinical reasoning into the future.[26]

Whilst the outcomes of this study show that inductive reasoning is associated with improved diagnostic accuracy, it must be emphasised that it will be most effective when utilised in a combined approach with Type 1 processing.[55,56] This additive model applies to both novices and experienced clinicians.[44,57] Inductive reasoning is an effective means of ‘cross-checking’ the results of intuitive processes,[13,58,59] including any emotional involvement which may have influenced these processes.[60] Care must be taken to ensure that while encouraging the development of inductive reasoning in students, they do not perceive that pattern recognition is a ‘dangerous’ and inferior cognitive process.[52] Evidence clearly shows that junior medical students, with appropriate training, are capable of utilising Type 1 reasoning to generate accurate diagnoses.[15,61] Recent research in the nursing field also emphasises the importance of intuition and the necessity for educators to support its use.[62] Indeed, one-dimensional, exhaustive problem-oriented approaches can result in cognitive overload, generating unmanageable amounts of data.[32] Another important benefit of a combined approach is its sensitivity to the principle that clinical reasoning development is highly dependent on an individual’s context or the state in which they are operating.[63] Ultimately multiple cognitive processes working simultaneously, with an individual's awareness of their respective limitations, provides the optimum framework for approaching the diversity of clinical problems faced by todays veterinary practitioners.[64]

Limitations and further study
This investigation was based on students from one university and thus we were unable to compare the impact of different curricula on the clinical reasoning approach. A multi-university study would provide more insight into the relationship between inductive reasoning and diagnostic accuracy because a wider variety of approaches could be observed. Furthermore, the students participating in this study were volunteers and as a result the characteristics of the cohort may have been different to that of the general student population. We minimised the impact of this limitation by ensuring that group assignment was based on previous examination results, meaning an even spread of academic ability. The fact that this study focused only on students may also have limited the clinical reasoning approaches observed. For example, their inexperience will have reduced their pattern-recognition capability. Further research could involve analysis of the problem-solving approaches used by more experienced veterinary clinicians.

In studies assessing the clinical approach to a case there is a risk of confusion over causality, particularly in observational studies. We minimised this risk by basing our analysis on first-hand approaches to the case rather than subsequent explanations of diagnoses.[41] Finally, the textual analysis in this study was conducted by one individual and thus there is a risk of subjectivity. We minimised this risk by calculating the IRS based on an objective set of pre-determined characteristics (Table 1) and ensuring that the assessments were examined blind to the DAS and group allocation of the individual.

In conclusion, these results contribute to a body of research proposing that inductive reasoning teaching delivered as part of an additive model, can improve the clinical reasoning skills of veterinary students. These skills will encourage the development of reflective veterinarians, resisting over-confidence and armed with the capacity to make accurate diagnoses.

Despite the limitations described, the recommendations made by this study remain valuable to veterinary educators striving to instil fundamental clinical reasoning skills into their students and in so doing reducing diagnostic error.

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Tables and Figures

Characteristics		Points Available
Defining the problem	e.g. using semantic qualifiers as described by Bordage and Lemieux[33]	2
Defining the system	Respiratory	1
	Cardiac	1
	Endocrine	1
Defining the location	Respiratory	1
	Cardiac	1
	Endocrine	1

Table I: Table showing characteristics used to calculate the IRS.

	G1	G2	T-test P value	Significance
DAS	-0.43	-0.92	P=0.40	Insignificant
IRS	5.65	5.88	P=0.50	Insignificant

Table II: Table showing the results of the T-test comparison of DAS and IRS, between G1 and G2.

Figure I: A scatter plot showing the relationship between IRS and DAS for all 47 students.

Figure II: A scatter plot showing the relationship between IRS and DAS for G1

Figure III: A scatter plot showing the relationship between IRS and DAS for G2