Education

Ineffectiveness of cognitive forcing strategies to reduce biases in diagnostic reasoning: a controlled trial

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ABSTRACT

Objectives: Cognitive forcing strategies (CFS) may reduce error arising from cognitive biases. This is the first experimental test to determine the effect of CFS training in medical students.
Methods: Students were allocated to CFS training or control during a 4-week emergency medicine rotation ($n = 191$). At the end of the rotation examination, students were tested using computer-based cases. Application of CFS could enable reduction of diagnostic error, as evidenced by identifying multiple correct diagnoses for the two cases prone to search satisficing bias (SSB) and uncommon diagnoses for the two cases prone to availability bias (AB). Two ''false positive'' cases were included to test for possible ''oversearching.''
Results: There were 145 students in the intervention and 46 in the control group. For the SSB cases, 52% of students with CFS training and 48% in the control group initiated a search for the second diagnosis ($\chi^2 = 0.13$, $df = 1$, $p = 0.91$). More than half (54%) correctly identified the second diagnosis in the CFS group, and 48% identified it in the control group. The difference was not significant ($\chi^2 = 2.25$, $df = 1$, $p = 0.13$). For the second diagnosis in the false positive cases, 64% of the CFS group and 77% of the control group incorrectly identified it. There were no significant differences between groups ($\chi^2 = 2.38$, $df = 1$, $p = 0.12$). In the AB cases, only 45% in each group identified the uncommon correct diagnosis ($\chi^2 = 0.001$, $df = 1$, $p = 0.98$).
Conclusions: The educational interventions suggested by experts in clinical reasoning and employed in our study to teach CFS failed to show any reduction in diagnostic error by novices.

RÉSUMÉ

Objectifs: Les stratégies de «forçage» cognitif (SFC) peuvent réduire le nombre d'erreurs découlant de la partialité cognitive. Il s'agit du premier essai expérimental visant à déterminer l'effet de la formation fondée sur les SFC, sur les étudiants en médecine.
Méthodes: Les étudiants ont reçu la formation fondée sur les SFC ou la formation habituelle durant un stage de 4 semaines en médecine d'urgence ($n = 191$). À la fin de l'examen relatif au stage, les étudiants ont été soumis à une analyse de cas informatisée. L'application des SFC pourrait permettre une réduction du nombre de diagnostics erronés, comme en témoignent la possibilité de plus d'un bon diagnostic concernant deux cas susceptibles de donner lieu au biais de recherche passable (BRP) et la pose de diagnostics rares concernant deux cas susceptibles de donner lieu au biais de disponibilité (BD). La liste comprenait également deux cas «faux positifs» pour vérifier la possibilité de «recherche excessive».
Résultats: Le groupe expérimental comptait 145 étudiants et le groupe témoin, 46. En ce qui concerne les cas susceptibles du BRP, 52% des étudiants ayant reçu une formation fondée sur les SFC et 48% des étudiants ayant reçu la formation habituelle ont entrepris une recherche sur le deuxième diagnostic ($\chi^2 = 0.13$; fonction de répartition [F(x)] = 1; $p = 0.91$). Plus de la moitié (54%) des sujets du groupe de SFC a considéré, à juste titre, le deuxième diagnostic comme bon contre 48% dans le groupe témoin. L'écart n'était pas significatif ($\chi^2 = 2.25$; F(x) = 1; $p = 0.13$). En ce qui concerne le deuxième diagnostic dans les cas «faux positifs», 64% des étudiants du groupe de SFC et 77% des étudiants du groupe témoin ont posé le mauvais diagnostic. Là encore, l'écart n'était pas significatif entre les deux groupes ($\chi^2 = 2.38$; F(x) = 1; $p = 0.12$). Quant aux cas susceptibles du BD, seulement 45% des participants dans chacun des groupes a bien reconnu le diagnostic rare ($\chi^2 = 0.001$; F(x) = 1; $p = 0.98$).
Conclusion: Les interventions didactiques préconisées par des experts en raisonnement clinique et appliquées dans l'étude décrite ici, visant à enseigner les SFC n'ont pas permis de réduire le nombre de diagnostics erronés, posés par les étudiants.

Keywords: cognitive error, diagnostic reasoning, instructional methods, medical education

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A number of studies have described the prevalence of diagnostic error.[1–4] In primary care settings, an estimated 7 to 17% of cases have some type of diagnostic error associated with them.[5] In the emergency department, medical error occurs in 3% of visits, with 70% of these errors being classified as a diagnostic error.[6]

Although most cases of diagnostic error are detected and resolved prior to serious patient harm, serious consequences can ensue. In fact, a substantial proportion of malpractice suits are related to diagnostic error.[4]

Despite the systematic description of the phenomenon, few studies have identified the root cause of diagnostic error. Although studies of medical management errors typically describe a multifactorial cause, some authors have claimed cognitive errors committed by physicians as the major, but easily correctable, source. Specifically, cognitive biases, the systematic errors of reasoning independent of specific content knowledge, are thought to play a significant role in diagnostic error.[7–11]

The central claim of these authors is that cognitive biases are the result of rapid, nonanalytic reasoning that neglects appropriate evidence and failure to employ a slower, conscious decision-making process, necessary for the correct diagnosis.[7,9] Multiple biases exist. Croskerry has catalogued 32 possible biases that may arise in diagnostic situations.[12] One example is "search satisficing bias" (SSB), a form of premature closure that occurs when the search for additional evidence stops once an obvious or prominent diagnosis is reached. This may lead physicians to miss a potential second diagnosis that may be detected through further investigation. Another example is "availability bias," in which a clinician makes a diagnostic decision on the ease of recall of similar cases and ignores base rates. Kahneman and colleagues established cognitive biases as universal features of human cognition using studies of everyday decision making by psychology undergraduates.[11] The influence of such biases in the different context of medical diagnostic error has been researched in a very limited manner.[13]

This lack of evidence has not discouraged the promotion of training programs to minimize cognitive bias.[10,11,14] Croskerry proposed that metacognitive training at the novice stage can decrease the impact of cognitive biases in future decision making.[7,8] Specifically, these programs claimed that metacognitive techniques (termed cognitive forcing strategies [CFS]) can identify specific biases, promote self-monitoring, and develop approaches to minimize biasing of diagnoses.[7,8,10,11,14] Despite their promise and widespread promotion, CFS programs have very limited evidence for their success in preventing diagnostic error in educational settings. Apart from a small pilot study conducted by Sherbino and colleagues,[15] no experimental evidence on the efficacy of a CFS program exists. The failure of CFS training in that study is limited by the small sample and lack of an adequate control group.

This study is an extension of the previous work using a larger sample of learners, longer follow-up, and a control group. The objective of this study was to determine the effect of CFS training on diagnostic error in senior medical students.

METHODS

Study design

This was a prospective, controlled trial of an education intervention. Ethics approval was granted by the McMaster University Faculty of Health Sciences Research Ethics Board.

Study setting and population

Senior medical students (final year of a 3-year curriculum) in clerkship at McMaster University completed a 4-week emergency medicine (EM) rotation in groups of 15 to 18 students. Participants in each rotation were recruited at the start of rotation and enrolled in the study for the duration of the rotation. A total of 198 participants in 11 rotations were recruited from September 2009 to February 2011.

Study protocol

The methods used in this study are identical to those described elsewhere.[15] The first eight rotations were allocated to receive CFS training, and the following three rotations served as controls. The initiation of the study in the middle of the final year of medical school (and bridging two respective class years) ensured that there was equitable distribution of previous clinical experience between the experimental and control groups. Recruitment of an equal number of controls was interrupted by a curriculum redesign of the EM rotation.

The CFS training was held during the first instructional week of each rotation. The educational intervention consisted of a 90-minute, interactive, case-based seminar of 15 students and one instructor following an outline of standardized Microsoft *PowerPoint* slides. The curriculum was refined based on feedback from local educational experts and medical students who piloted the initial version. Students were taught two biases: search satisficing and availability. With SSB, the clinician may identify one diagnosis but miss a second. With availability bias, clinicians may identify incorrect, common diagnoses and miss a correct, but uncommon, diagnosis. Training session facilitators were expert EM clinicians experienced with teaching CFS. For each instructional case, the provided information included patient demographics, chief complaint, history of present illness, past medical history, medications, allergies, vital signs, general appearance, physical examination findings (e.g., cardiac and respiratory examinations), and digital images of either an electrocardiogram (ECG) or an x-ray. The design and delivery of CFS teaching were modeled after Croskerry's commonly cited model.[9] The educational intervention was refined with feedback from the pilot sample and local CFS experts.

The seminar introduced cognitive biases, the prevalence and effect of diagnostic error, and the application to specific pathologies. CFS teaching included self-monitoring during decision making, potential bias identification, and active employment of a cognitive process to counter a potential bias. Students then individually practiced CFS using given clinical cases by developing a diagnosis and treatment plan for each case. Feedback was provided to the group based on the range of responses once the correct diagnosis was revealed. Generalizability of these biases was also taught. Students were explicitly told that each bias can occur in multiple contexts. They were provided with examples and invited to contribute their own examples to the group discussion.

On alternate rotations, diagnostic tests and biases were counterbalanced. For the first group, SSB was taught using x-rays and availability bias using ECGs, and for the second group, search satisficing was taught with ECG materials and availability with x-rays. (Specific materials differed because the task requirements were different.)

The control group received no specific, scheduled instruction on CFS. During their first instructional (i.e., nonclinical) week of the rotation, the 90-minute session was left for self-directed study.

Measurements

At the end of the 4-week rotation, a 2-hour mandatory, computer-based examination was conducted as part of the clerkship rotation. As a component of the 48-question examination, students were presented with six testing cases as part of the examination. Each testing case used a free text box asking the student to input the correct diagnosis(es) as appropriate (Appendix). At the conclusion of the end-of-rotation examination, students were informed that the six questions relating to CFS training were not included in their written examination score. Students could request that their blinded, anonymous information be removed from pooled analysis. Blinded answers were scored by one of the expert authors using a predesigned scoring rubic.

Each case consisted of a clinical vignette (including a detailed history and physical examination) and either an x-ray or an ECG, which the students used to establish a diagnosis. All correct diagnoses were recorded. All cases were designed by expert clinicians and pilot tested. Six cases were associated with potential biases, with the others serving as filler. SSB consisted of one case using an x-ray and one using an ECG. Each case had two correct diagnoses. Two "false positive" search satisficing cases, for which there is no correct second diagnosis, were also included to determine if students were "oversearching" for a secondary diagnosis. Availability bias was tested with one case using an x-ray and one case using an ECG, for which a common diagnosis was possible but incorrect, whereas an uncommon diagnosis was correct. A list of cases and diagnoses is presented in Table 1.

Data analysis

All analyses were conducted with the Cochran-Mantel-Haenszel χ^2 test of conditional independence with case type (x-ray/ECG) as the stratification variable. The Breslow-Day χ^2 test of homogeneity was used to determine if performance varied between x-ray and ECG cases. For SSB, we compared the proportion of students in the CFS group and the control group who searched for a second diagnosis and the proportion whose second diagnosis was correct. Similarly, the proportion that identified a second diagnosis was

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Table 1. Cases and diagnoses

Bias type	Diagnostic test	Primary diagnosis	Secondary diagnosis
Search satisficing	X-ray	Metacarpal fracture	Distal phalynx dislocation
Search satisficing	ECG	ST elevation myocardial infarction	Atrial fibrillation
		Primary diagnosis	Examples of incorrect additional diagnoses
False positive	X-ray	Pediatric supracondylar fracture	Olecranon, radial head, capitulum, trochelar fractures, etc.
False positive	ECG	Sinus bradycardia	First and second-degree AV blocks; ST segment changes consistent with cardiac ischemia, etc.
		''Uncommon'' correct diagnosis	Examples of ''common'' incorrect diagnoses
Availability	X-ray	Pulmonary abscess	Pneumonia, lung cancer, etc.
Availability	ECG	Pericarditis	ST elevation myocardial infarction, left ventricular hypertrophy, etc.

AV = atrioventricular; ECG = electrocardiogram.

compared for the false positive cases (for which there was no second diagnosis). For availability bias, we compared the proportion that identified the uncommon diagnosis. All analyses were conducted using *SPSS* version 16 (SPSS Inc., Chicago, IL). There was no a priori determination of what constituted an educationally significant improvement in performance because there is no previous research in this field to guide such an estimate. However, based on our sample size, we had 80% power to detect a difference of 20% with a two-tailed alpha value of 0.05 when comparing the intervention group to the control group to detect a second diagnosis for the SSB cases and to identify the uncommon, correct diagnosis in the availability bias cases.

RESULTS

Of the 198 potential students, 145 students were enrolled in the intervention group and 46 in the control group. Seven students were unavailable for follow-up because their clinical placement was in a distant community site, which used a paper examination instead of the computerized version. Overall proportions for each group are reported below by bias and case type, along with the results of the analysis. No effect of counterbalancing was detected using the Breslow-Day test of homogeneity for all analyses. Thus, the subgroups were collapsed into comparisons of experimental versus control groups.

For the SSB cases, 52% of students with CFS training and 48% in the control group initiated a search for the second diagnosis ($\chi^2 = 0.13$, $df = 1$, $p = 0.91$). Of these, 54% correctly identified the second diagnosis in the CFS group and 48% did so in the control group; the difference was not significant ($\chi^2 = 2.25$, $df = 1$, $p = 0.13$; Table 2).

False positive cases were designed to see if CFS training promoted oversearching for the second diagnosis. Sixty-four percent of the CFS group and 77% of the control group incorrectly identified a second diagnosis. There were no significant differences between groups ($\chi^2 = 2.38$, $df = 1$, $p = 0.12$; Table 3).

In the availability bias cases, only 45% of the participants in both groups identified the uncommon correct diagnosis, with no difference between groups ($\chi^2 = 0.001$, $df = 1$, $p = 0.98$; Table 4).

Table 2. Performance on search satisficing bias cases

Group	Correctly identified first diagnosis (%)	Searched for second diagnosis (%)	Correctly identified second diagnosis (%)
CFS training	144 (99.5)	76 (52)	45 (54.5)
Control	46 (100)	23 (48.5)	11 (47.8)

CFS = cognitive forcing strategies.

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Table 3. Performance on false positive cases

Group	Correctly identified diagnosis (%)	Identified a second (nonexistent) diagnosis (%)
CFS training	111 (76.5)	94 (64.5)
Control	25 (55)	34 (76.7)

CFS = cognitive forcing strategies.

DISCUSSION

This study builds on our earlier work by using a larger sample size, increasing the period of follow-up, and employing a control group.[15] Similar to the earlier study, we found that for both biases, CFS training resulted in only half of the experimental group avoiding a diagnostic error and making the correct diagnosis(es). However, this was not significantly different from the diagnostic accuracy of the control group. In both the experimental and control groups, the proportion of participants identifying a second diagnosis was as high for the false positive cases as the true search satisficing cases. CFS training (as implemented in this study) had no impact on preventing diagnostic error.

One possible explanation for the failure of CFS in this study is that it purports to target biases arising from nonanalytic reasoning. If novices are not using nonanalytic reasoning, CFS may be of little benefit. The overall diagnostic accuracy of both experimental and control groups suggests that these "novices" may lack sufficient experience to employ nonanalytic reasoning. There is some evidence that novices do tend to rely on conscious, analytic reasoning, employing algorithms or feature counts to determine a diagnosis.[16] Kulatunga-Moruzi and colleagues showed that preclerkship medical students relied on analytic and deliberate strategies to make diagnoses when presented with dermatologic slides.[17]

A second explanation is that a "ceiling" on analytic processing was achieved, and the benefits of CFS could not be accessed. Most analytic processes are limited by the amount of working memory of the learner, as well as the intrinsic and extrinsic cognitive load of the activity.[18] Further encouragement to engage in additional circumspection (particularly in a novice, where, by definition, more analytic than nonanalytic reasoning is carried out) may simply overwhelm an individual's cognitive load without any effect on outcomes.[19]

Third, the six cases may not have been complex enough to benefit from analytic reasoning (by definition, CFS is a form of analytic reasoning). A number of studies have suggested that analytic reasoning benefits complex or ambiguous cases, but in straightforward (i.e., simple) cases, diagnostic accuracy is not improved, whether nonanalytic or analytic reasoning is used.[20–22] However, recent research we conducted suggests that this hypothesis may be incorrect.[23] In a study of participants completing the Medical Council of Canada's Qualifying Examination Part 2, participants were exposed to a range of simple and complex clinical cases (e.g., subconjunctival hemorrhage, glyburide-induced hypoglycemia in acute renal failure). The time to diagnosis was inversely proportional to the accuracy of the diagnosis. Our results suggest that analytic reasoning (which requires a longer diagnostic process) does not necessarily lead to improved accuracy, regardless of the complexity of the case. Thus, the failure of CFS (i.e., analytic reasoning) to improve diagnostic accuracy in this study seems congruent with our previous work.

Finally, there is also reason to challenge the assumption that diagnostic errors arise via nonanalytic reasoning and that interventions should be designed to counter the biasing of this reasoning process. There is

Table 4. Performance on availability bias cases

Group	Identified common incorrect diagnosis (%)	Identified uncommon correct diagnosis (%)
CFS training	141 (97.2)	66 (45.2)
Control	41 (89.1)	21 (44.6)

CFS = cognitive forcing strategies.

considerable evidence that encouragement to use both analytic and nonanalytic strategies, where possible, is of advantage to novices.[24–27] The few studies that have examined cognitive biases in medical experts find that they may be more susceptible to bias than novices. For example, Eva and colleagues showed that experienced physicians were prone to the primacy effect, a cognitive bias describing the tendency to choose an incorrect diagnosis when its features are presented earlier in the case,[26] in comparison with features of the correct diagnosis that are presented later.[28] This suggests the intriguing possibility that the primary beneficiaries of CFS may be experts and not novices, in contrast to the arguments suggested in diagnostic reasoning editorials. Future research should explore this hypothesis.

LIMITATIONS

This study is limited by the restricted range of diagnoses and diagnostic tests used to evaluate CFS. A wider range of clinical cases and diagnostic information may constitute a more thorough assessment of CFS. The artificial testing situation may also have influenced the effectiveness of CFS. Although there were no significant differences detected between groups, there was some suggestion that the control group had slightly lower accuracy and slightly higher false positive rates.

This study is also limited by the imbalance of the size and lack of randomization between the experimental and control groups. Contamination between groups might also have occurred; however, the experimental and control groups were composed of different medical school years, thus potentially mitigating contamination. Nonetheless, these issues might mean that a type II error occurred, where a difference between groups is present, but the study did not detect it.

A final limitation of this study is that the follow-up assessment of participants occurred more than 3 weeks after instruction. Education experts would question the impact of a single intervention to change a cognitive bias at a remote testing interval. Our previous pilot study demonstrated no effect in the immediate testing period.[15] Nonetheless, multiple educational reinforcements of CFS may increase the impact on diagnostic errors. However, the CFS training in this study is consistent with the other education sessions offered during the EM rotation and adheres to the educational design for CFS training advocated in the literature.[7,8]

CONCLUSION

The educational interventions suggested by experts in clinical reasoning and employed in our study to teach cognitive forcing strategies failed to show any reduction in diagnostic error by novices. Future studies with more experienced physicians are required to see if CFS may be effective in this population.

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