# Development of an expert system for aiding migraine diagnosis

Danny Kopec, Gennady Shagas, Jay Selman*, Daniel Reinharth*, Suzanne Tamang

*Department of Computer and Information Science, Brooklyn College and * Columbia University College of Physicians and Surgeons, New York, NY*

Correspondence and reprint requests to:
Danny Kopec, Department of Computer and Information Science,
29000 Bedford Avenue, Brooklyn, NY 11210
e-mail: kopec@sci.brooklyn.cuny.edu

**Abstract**

Objective: To design and develop a prototype expert system to aid physicians in diagnosing migraines.

Design: Developmental process.

Setting: Since the system is web-based, it is accessible to any physician or health care provider anywhere in the world.

Methods: The knowledge acquisition process was facilitated by a physician who served as our domain expert to identify the application's key elements. We have included the essential questions and rules necessary for building an expert system to diagnose migraine headaches and distinguish them from other types. The application utilizes a data collection form, the C Language Integrated Production System (CLIPS), and a program with the appropriate rules, which are written in the CLIPS language. The front end and middle tier is built, and the connection between the HTML front end and the expert system shell CLIPS is established. We also created an XML representation of the International Classification of Diseases, 9th Revision Clinical Modification (ICD-9-CM), including the disease category 346 (Migraine), and published it on the Web. Data from 6 patients with a clinical diagnosis of migraine were used to validate the system

Results: For each of the 6 cases the system indicated that the probability that the migraine diagnosis was greater than 75%. The probability for 14 different subtypes of migraines ranged from 0% to 97%. The system processing time ranged from 3 to 30 seconds, depending upon the number of questions and embedded subtypes.

Conclusion: We have developed an expert system to facilitate the diagnosis of migraines and their sub-types. Further development and evaluation of the clinical accuracy and ease of use are necessary before it can be recommended for routine clinical use.

## INTRODUCTION

Headaches, one of the most common symptoms presented to physicians, appear in a variety of forms. As such, they may represent a primary problem or be a manifestation of many different diseases. An accurate diagnosis is an essential prerequisite for effective treatment. Headaches present a challenge as they can be caused by more than 100 diseases[1], and accurate diagnosis of the cause is essential to optimal treatment. There are at least 20 different types of migraines. Individualised treatment is more effective than nonspecific therapies in relieving symptoms, preventing attacks and maintaining patient function [2]. They are frequently underdiagnosed or misdiagnosed as tension type headaches [3-6]. Consequently many patients do not receive appropriate and optimal treatment and continue to suffer attacks with associated disabling symptoms.

The International Headache Society has proposed a classification scheme for headaches including rules to diagnose migraines [7,8]. Since these seem over-simplified, we have developed a web-enabled application using more sophisticated rules to aid diagnosis of migraines. The rules for the application are represented in the C Language Integrated Production System (CLIPS) expert system shell. CLIPSis a product development and delivery expert system tool which provides a complete environment for the construction of rule and/or object based expert systems [9].

### Methods

The CLIPS expert system shell provides a cohesive tool for handling a wide variety of knowledge with support for three different programming paradigms:

- Rule-based
- Object-oriented
- Procedural.

Rule-based programming allows knowledge to be represented as heuristics, or 'rules of thumb', which specify a set of actions to be performed for a given situation. Object-oriented programming allows complex systems to be modeled as modular components, which can be easily reused later. The procedural programming capabilities are similar to capabilities found in languages such as C. CLIPS can be embedded within procedural code, called as a subroutine, and integrated with languages such as C and Java. CLIPS can easily be extended by a user through the use of several well-defined protocols, and it can be implemented in web-based applications using the Common Gateway Interface (CGI) bin or Java servlets.

The clinical diagnosis of migraines is based on headache characteristics and associated symptoms, particularly nausea and vomiting. Figures A3 and A4 shows the form containing the questions identified as relevant to the diagnosis. The program itself can dynamically generate the forms, which may be completed on the computer or in a printed format. If paper forms are used then data entered from the form to a computer will need to be validated and corrected, if necessary.

The ICD-9-CM classifies migraines into 20 different sub-types (icd-10?) [10]. To test our system, research was performed on a subset of questions and types of migraines. We

selected only 10 of these questions for our research, and created the appropriate program. From the 20 known types of migraines we randomly selected 14 types. The rules we created are based on existing criteria [6-7]; however, we introduced additional artificial dependencies for the purpose of testing system performance. The certainty of each diagnosis is calculated by three parameters; these parameters are chosen by the program according to certain rules related to the answers given.

These simplifications are necessary to create a prototype of the expert system for migraines, and to test the rules and performance, and to later extend the system. We also introduced additional complexity into the CLIPS rules to increase the accuracy of migraine diagnosis.

To test our system we entered answers obtained by interviewing six patients diagnosed with migraines. The data was entered directly using an existing CLIPS interface. The user's dialogue with the CLIPS application is presented in Appendix B, Section 3.
We also evaluated the execution time of the system with respect to the number of questions asked and the number of migraine types embedded in the system.

*Result*

**Table 1** Migraine Expert System Questions and Answers (cases 1… 6)

| # | Question | Answers for case | | | | | |
|---|---|---|---|---|---|---|---|
| | | **#1** | **# 2** | **# 3** | **# 4** | **# 5** | **# 6** |
| 1 | Age (in years)? | 0-29 | 30-49 | 50-69 | 70-up | 0-29 | 50-69 |
| 2 | Gender? | female | male | female | male | male | female |
| 3 | Does your headache occur during menstruation, ovulation, menopause or oral contraceptives? | yes | - | - | - | - | - |
| 4 | Does your headache BEGIN on right side? | yes | yes | no | yes | no | no |
| 5 | How does your headache feel? | dull | aching | throbbing | unknown | aching | dull |
| 6 | Does pain interfere significantly with school* and/or work activity? | yes | no | no | no | no | no |
| 7 | Does vomiting accompany the headache? | no | yes | no | yes | yes | no |
| 8 | Does nausea accompany the headache? | yes | - | no | - | - | no |
| 9 | The number of headaches per month? | 0-2 | 6-9 | 10-19 | 0-2 | 3-5 | 6-9 |
| 10 | Can your headache be triggered by certain foods, odors, stress or weather changes? | yes | no | yes | no | no | yes |

***Note:** School would apply to an adolescent or young adult in graduate school.

Here we present only ten questions, but we are currently working on the comprehensive program containing the set of all available questions and rules.

## RESULTS

The results from the CLIPS system for the 6 patients with a known diagnosis of migraine are shown in table 2 below: In all patients the certainty for a diagnosis of migraine is at least 75%, but the sub-diagnoses vary from 0% to 97%. For example Patient 1 has 3 possible types of migraine with the certainty of Horton's neuralgia being highest (88%), and for atypical migraine being lowest (40%). Missing values for the other 11 types of migraine indicate that the certainty of such types is negligible. For the 6 patients evaluated, for the 14 different types of migraine, the system helps to narrow 84 (14x6) possible diagnoses down to 48 (3+11+8+13+7+4).

**Table 2** Certainty of a Specific Diagnosis for Various Cases

| # | ICD-9 Code | Migraine description | Certainty for each Case Number (%) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | #1 | # 2 | # 3 | # 4 | # 5 | # 6 |
| 1 | 346.0.1 | Migraine preceded by ... | - | 40 | 92 | 36 | - | 40 |
| 2 | 346.0.2 | Migraine with aura | - | - | - | 20 | 20 | - |
| 3 | 346.1.1 | Atypical migraine | 40 | - | - | 20 | 20 | - |
| 4 | 346.1.2 | Sick Headache | - | 36 | 36 | 59 | 20 | - |
| 5 | 346.2.1 | Cluster headache | 64 | 20 | - | 36 | - | - |
| 6 | 346.2.2 | Histamine cephardia | - | 36 | 36 | 59 | - | 40 |
| 7 | 346.2.3 | Horton's neuralgia | 88 | 20 | 20 | 20 | - | 80 |
| 8 | 346.2.4.1 | Migraine abdominal | - | 20 | - | 36 | - | - |
| 9 | 346.2.4.2 | Migraine basilar | - | 76 | - | 76 | 76 | - |
| 10 | 346.2.4.3 | Migraine lower half | - | 40 | 40 | 68 | 40 | - |
| 11 | 346.2.4.4 | Migraine retinal | - | 40 | - | 68 | 40 | - |
| 12 | 346.2.5 | Neuralgia | - | 40 | 40 | 20 | - | - |
| 13 | 346.2.8.1 | Migraine hemiplegics | - | - | 97 | - | - | 80 |
| 14 | 346.9 | Migraine, unspecified | - | 40 | 40 | 68 | 40 | - |

The precision of the system may be improved by increasing the number of questions. As shown in Figure 1 this increases the time that the system takes to process the data. This time increase, requiring a few additional seconds, is however of no clinical significance. The time to process the data is also affected by the number of migraine types embedded into the expert system. Increasing the number from the 5 most common migraine diagnoses to 20 types increases the execution time from 3 to 17 seconds (see Figure 1). Again this increase in time is of no clinical significance.

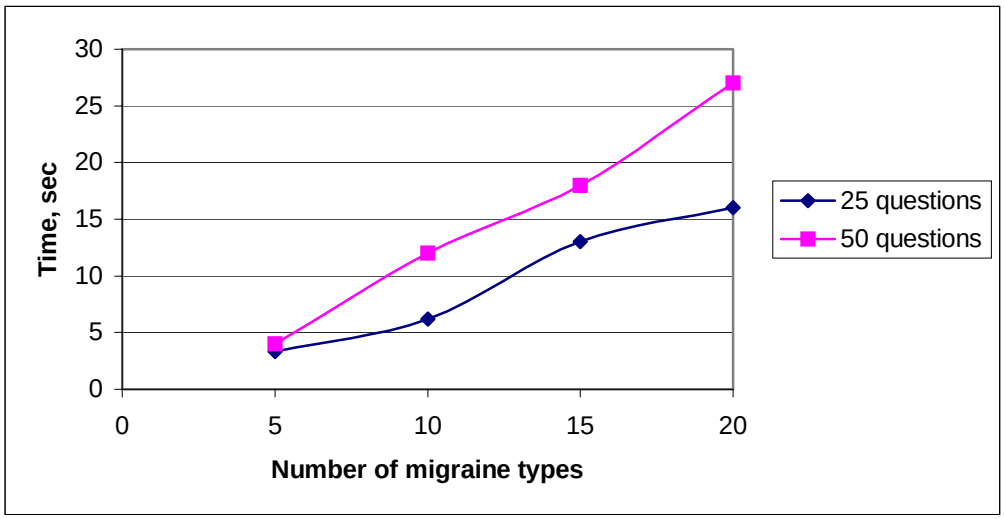


**Figure 1** The execution time for the CLIPS procedure with respect to the number of questions asked and the number of migraine types embedded into the system.

## DISCUSSION

Recent advances in understanding the pathophysiology of migraine, combined with better pharmacotherapy, have improved treatment of migraines with respect to relieving symptoms, preventing attacks and maintaining functionality. However for patients to benefit from appropriate therapy, accurate diagnosis of migraines is essential. When physicians fail to ask all the relevant questions, they may miss the diagnosis. This is demonstrated by a recent study which found that the documented history was inadequate to exclude the diagnosis of migraine in two-thirds of cases in which a diagnosis of non-migraine headaches was made [6]. Data from other studies and surveys have also confirmed that migraine is frequently under-diagnosed or misdiagnosed as tension headaches [2-5].

Our system aids the diagnosis of migraines by asking the essential questions. The system was tested using only 10 questions, but 23 essential questions have been identified for helping to distinguish migraines or other headaches. More questions should improve discrimination. Some of these questions may be omitted depending on answers to previous questions. For example the question '*Does your headache occur during menstruation, ovulation, menopause or oral contraceptives*?' will appear only if the answers to the previous questions '*Age (in years)?*' and '*Gender*?' are *'0-29 or 30-49'* and '*Female,*' respectively.

The system has been developed using the CLIPS expert system shell, as this tool provides a complete environment for the construction of rule and/or object based expert systems [9]. It can include a number of features including support for modular design and partitioning of a knowledge base, static and dynamic constraint checking of slot values and function

arguments, and semantic analysis of rule patterns to determine if inconsistencies could prevent a rule from firing or generating an error.

While the application is intended primarily for physicians, patients could use a modified version. This could be provided as either an online or stand-alone application, but an online online approach is better for new data collection and updating rules. The procedure requires about 1 minute to enter the answers to the questions and execute the expert system. To provide likely diagnoses takes less than 30 seconds. Depending upon the patient's symptoms, the system can reduce the number of possible subtypes of migraine by almost 50%. We estimate that use of such a system during a typical consultation for headaches will save several valuable minutes of the physician's and patients' time. It should also reduce the need for unnecessary investigations. Through both these mechanisms it should produce cost-savings. However this and the system's ability to improve migraine diagnosis including differentiating them from tension headaches remains to be proven.

**Acknowledgement:**

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## Conclusion

We have created a program, written in the CLIPS language for expert systems, to aid the diagnosis of migraines and to distinguish them from headaches. We have identified essential questions necessary for building an expert system that distinguishes migraines from headaches. The execution time depends on the number of migraine types embedded in the expert system. The time varies from 3 seconds for the five most common migraine cases to 17 seconds for the entire set of 20 types of migraine according to the ICD-9-CM classification. We also created an XML representation of the ICD-9-CM including disease category 346 (Migraines), and published it on the Web. The clinical accuracy of the system and its benefits remain to be established.

## References

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**Appendix A**

The research application prototypes were developed on both UNIX and Windows platforms using the following techniques: data mining, on-line transaction analytical processing,
Open source and freeware tools such as Java, MySQL database, Apache Web server, and CLIPS Expert System shell were used in the development process.
The graphic user interface (GUI) and presentation layer are written in HTML and JavaScript, while the Application and data manipulation layers are written in Common Gateway Interface (CGI) Perl script (Figure 3). In our present implementation, data is collected in the XML format as a file for future analysis and sent by e-mail.

A Java extraction transformation loading (ETL) procedure was used to transform the source text file into an XML file. It was then utilized to build the XML representation of the original ICD-9-CM. The Migraines and Headaches Application Form Revision 1.1.3 was developed and published on the Web. The Perl script takes the input from a form, sends it to a specified email address, appends information to the XML file and returns a confirmation page

## Appendix B: Migraines and Headaches Application

*Section 1. Migraine Application Schema and GUI*

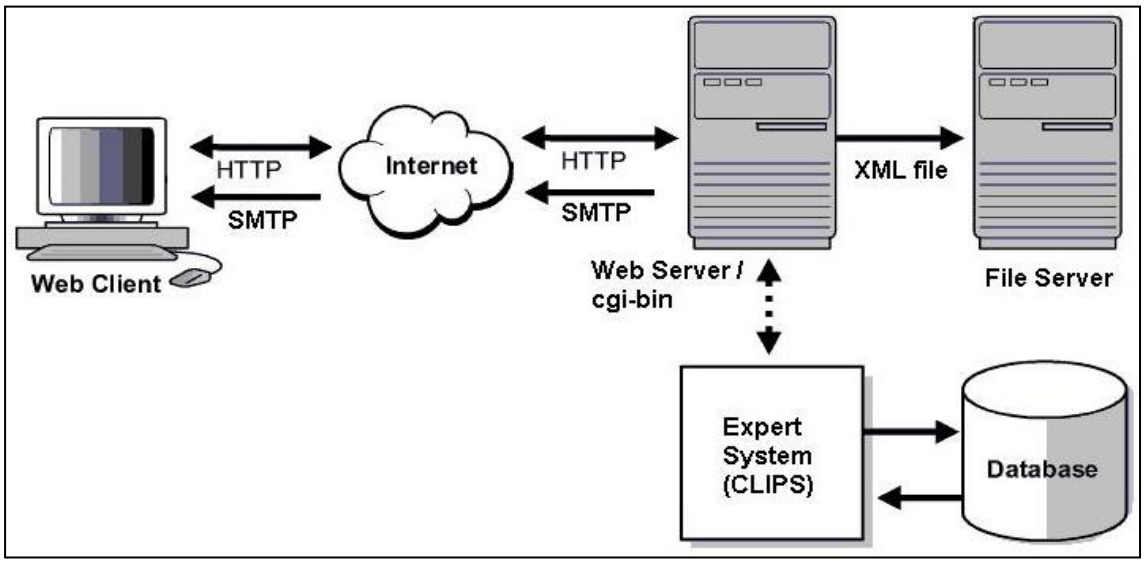


**Figure B.1.** The Migraine / Headaches Application Schema

```
<?xml version="1.0" encoding="UTF-8" ?>
- <ICD-9-CM>
  - <topic name="Classification of Diseases and Injuries">
      <group number="1">Infectious and Parasitic Diseases</group>
      <group number="2">Neoplasms</group>
      <group number="3">Endocrine, Nutritional, and Metabolic Diseases and Immunity
        Disorders</group>
      <group number="4">Diseases of the Blood and Blood-Forming Organs</group>
      <group number="5">Mental Disorders</group>
    - <group number="6">
        Diseases of the Nervous System and Sense Organs
      - <diseases numbers="340-349">
          <diseasesclass>Other disorders of the central nervous system (340-349)
            </diseasesclass>
        - <category id="346">
            <categoryname>Migraine</categoryname>
          - <subcode id="346.0">
              <subcodename>Classical migraine</subcodename>
              <disease id="346.0.1">Migraine preceded or accompanied by transient focal
                neurological phenomena</disease>
              <disease id="346.0.2">Migraine with aura</disease>
            </subcode>
          - <subcode id="346.1">
              <subcodename>Common migraine</subcodename>
              <disease id="346.1.1">Atypical migraine</disease>
              <disease id="346.1.2">Sick headache</disease>
```

**Figure B.2.** International Classification of Diseases (ICD-9-CM) (Fragment)

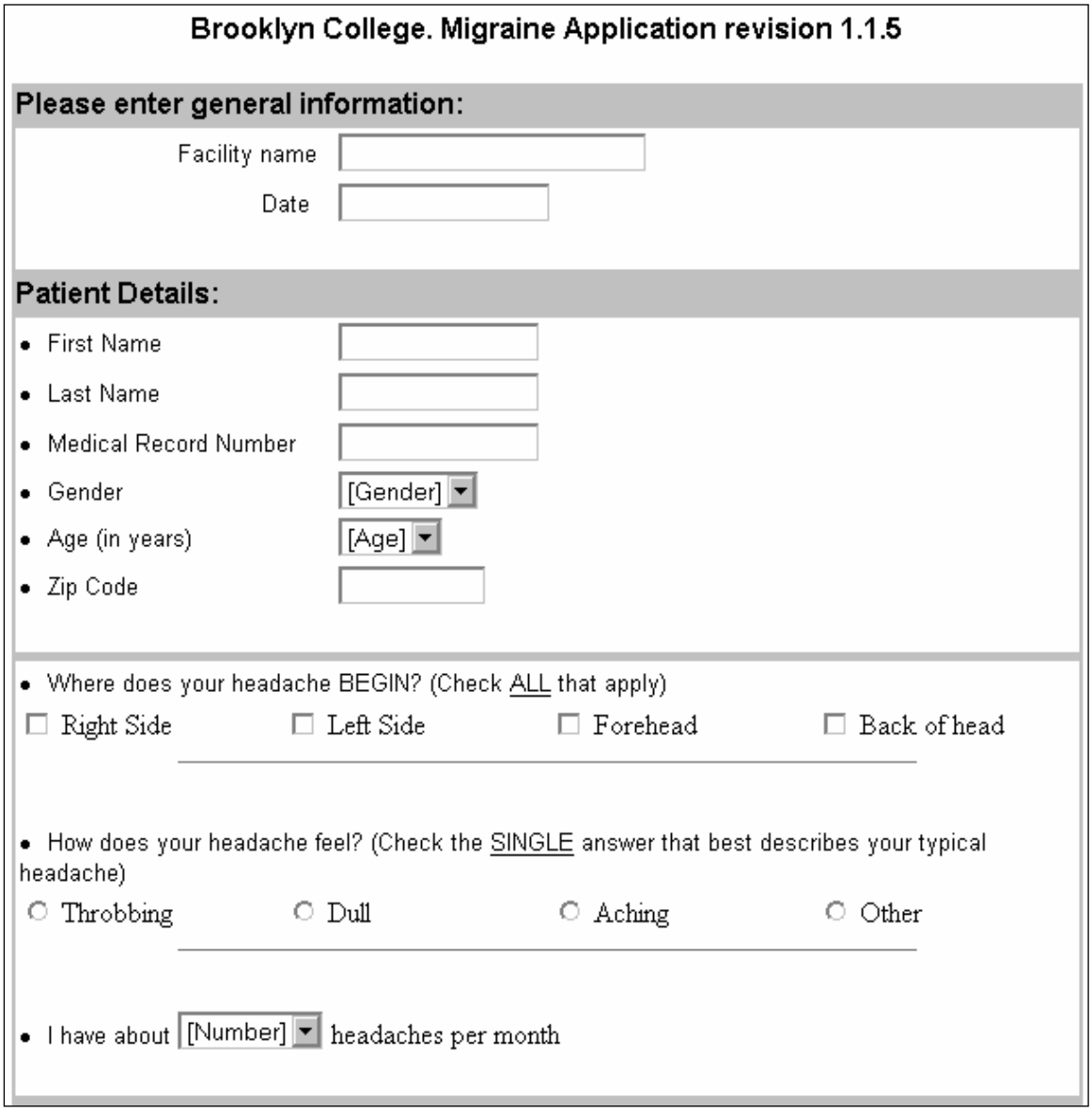


**Figure B.3.** Migraine Application HTML Form (Fragment – upper part)

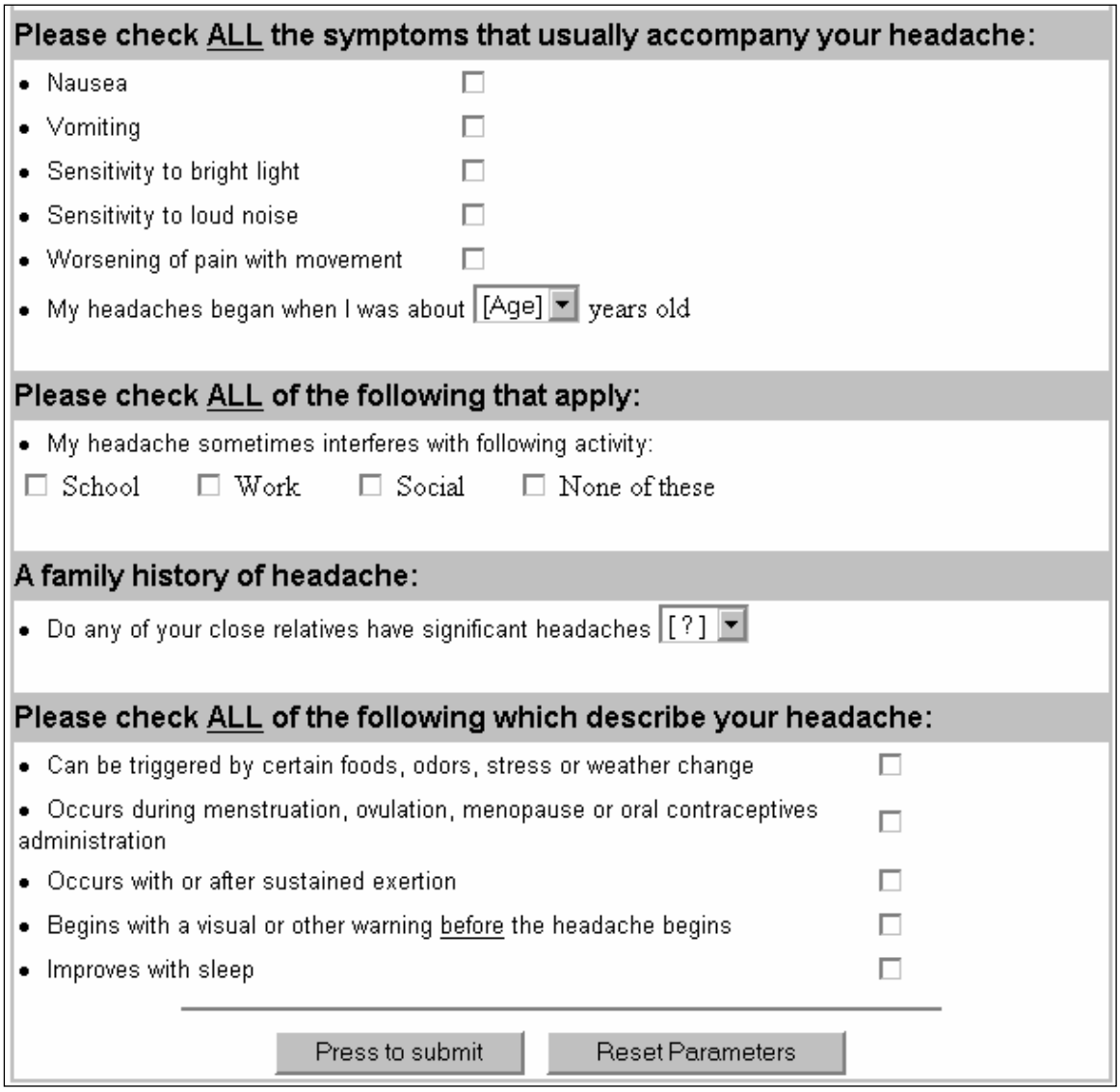


**Figure B.4**. Migraine Application HTML Form (Fragment – lower part)

**Note 1.** Most of the questions are based on the identification of headache syndromes in accordance with the International Headache Society (HIS) or the World Health Organization's International Classification of Diseases (ICD-10).
**Note 2.** School would apply to an adolescent or young adult in graduate school.

*Section 2. Patients' interaction with CLIPS system*

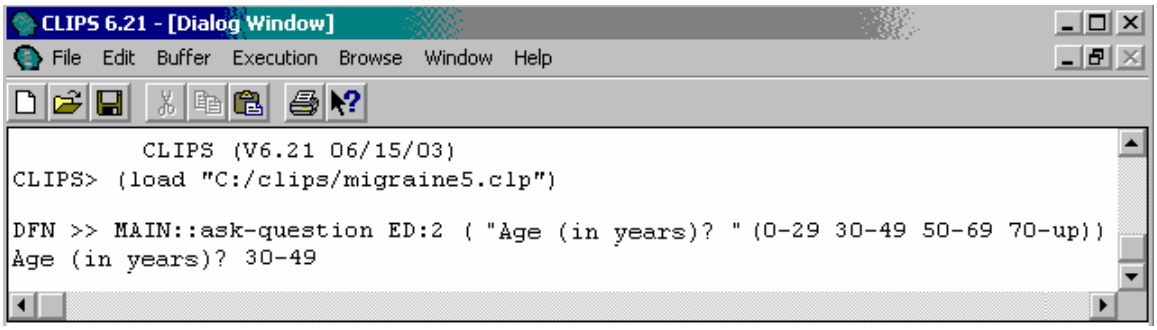


**Figure B.5**. User's dialogue with CLIPS application (fragment)

The answers from six patients diagnosed with migraine were obtained from interviews. The data was entered using the CLIPS interface. Patients' potential diagnoses are presented in Table 2.

Patient # 1 Dialog with the CLIPS system:

CLIPS: "Age (in years)?" (0-29 30-49 50-69 70-up) /* valid answers, see Table 1 */
Patient: 0-29.

CLIPS: Gender? (Male/Female)
Patient: Female.

CLIPS: Does your headache occur during menstruation, ovulation, menopause or oral contraceptives? (Yes/No)
Patient: Yes.

CLIPS: Does your headache BEGIN on right side? (Yes/No)
Patient: Yes.
CLIPS: How does your headache feel? (throbbing dull aching other unknown)
Patient: Dull.

CLIPS: Does pain interfere significantly with school activity? (Yes/No)
Patient: Yes.

CLIPS: Does vomiting accompany your headache? (Yes/No)
Patient: No.

CLIPS: Does nausea accompany your headache? (Yes/No)
Patient: Yes.

CLIPS: The number of headaches per month? (0-2 3-5 6-9 10-19 20-up)
Patient: 0-2.

CLIPS: Can your headache be triggered by certain foods, odors, stress or weather changes? (Yes/No)

Patient: Yes.