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Adaptive Feedback Evaluation

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Abstract: - Feedback is a powerful educational tool which would substantially improve the learning. Feedback would be integrated into Computer Adaptive Testing (CAT) systems to support the learner. This paper presents various types of adaptive feedback which depend on the learner's cognitive, emotional and conational state. It also presents AFE (Adaptive Feedback Evaluation), a framework for evaluating adaptive feedback in CAT systems. It includes twenty two criteria for evaluating the adaptive feedback in CAT. It would be useful for analysts, designers, developers and evaluators of CAT systems to make appropriate decisions.

Key-Words: - **A**daptive feedback, adaptive testing, evaluation, personalization, quality.

1 Introduction

CAT (Computer Adaptive Testing) systems are spreading in many fields [1, 2, 3]. The CAT system presents to the learner questions that are tailored around her performance level. She does not answer questions that are too difficult or too easy for her. This happens because the CAT system continuously assesses the learner's performance and chooses questions to present to her that have difficulty level appropriate for her. If the learner answers correctly a question, then the CAT system presents to her a more difficult question, otherwise it presents to her an easier question [4, 5].

Feedback is an important factor in learning. It can support the learner to enhance her knowledge, abilities, competences and strengths, to prevent her failures and mistakes, to correct her misconceptions and errors, and decrease her inefficiencies and weaknesses. Feedback would play an essential role in CAT. The feedback may support the learner at the cognitive, emotional or conational dimension. The feedback may advise and help the learner not only on answering the test questions and solving the test problems, but also in using the user interface, the input-output devices, the CAT system, the communication and collaboration facilities (e.g. email, chat, video conferencing). It may inform her on the correct-wrong answers, as well as comment, explain and elaborate them. It may also support her to select the next question and navigate the test. In addition, it may support her emotionally and motivationally. Finally, it may inform her on her results, achievements, strengths and weaknesses.

However, the integration of feedback in CAT systems is not an easy process. It needs careful requirements analysis, planning, design, development, evaluation, redesign, etc. This paper presents AFE (Adaptive Feedback Evaluation), a framework for evaluating the adaptive feedback in CAT systems. It presents a set of evaluation criteria that are important for the successful integration of the feedback in the CAT systems.

Previous research on feedback [6, 7] analyzes the cognitive feedback. Two elements are considered: verification and elaboration. Verification is the information that the answer is correct or wrong. Elaboration is any extra information beyond verification that guides the learner toward the correct answer. Three basic types of elaboration are considered: i) task specific, as in a restatement of the correct answer or inclusion of multiple-choice alternatives, ii) instruction-based, an explanation or an excerpt from the lesson text, and iii) extra-instructional, as in examples or analogies that were not part of the original instruction. The cognitive feedback is classified into the following categories: i) No feedback, ii) Knowledge of Response (it verifies whether the learner's answer is correct or wrong) , iii) Answer Until Correct (it asks the learner to try again until she answers correctly), iv) Knowledge of Correct Response (it indicates the correct answer), v) Topic contingent (it verifies the answer and elaborates on the general topic), v) Response contingent (it verifies the answer, explains why the correct answer is correct and the wrong answer is wrong and elaborates on it), vii) Bug related (it verifies the answer and presents common errors made by learners), and viii) Attribute isolation

(it verifies the answer and highlights the central attributes of the target concept). The following functions are assigned to the cognitive feedback: Confirming conditions, Adding information, Replacing or overwriting prior knowledge, Tuning understandings, and Restructuring schemata [8].
This paper considers not only the cognitive feedback but also emotional and conational feedback (section 2). It also presents an evaluation framework with 22 criteria to assess the feedback's quality (section 3). Finally, it presents the conclusions.

2 Adaptive Feedback types

The feedback may support the learner at the cognitive, emotional or conational mind dimension. It may be presented to the learner before she answers every question and after she answers it. Next, we present various feedback types that would be used in CAT.

Pre-Answer Cognitive Feedback	
Guidance	it guides the learner on how to use the CAT system.
Availability-Restrictions	it informs the learner on the currently available and restricted resources (e.g. email, search engine, Web, FAQ, software), and actions.
Orientation	it orientates the learner about the question, i.e. its corresponding subject, its importance, its difficulty level, its possible scores, its possible hints, the ability to be tested, its time, etc.
Organization	it helps the learner to organize her effort, energy and time to answer correctly the question.
Warning	it warns about common errors made by learners due to misconceptions or carelessness.
Hint	it provides extra relevant knowledge on the question, or a first step towards the correct answer.
Alternative	it presents to the learner the question in alternative media and format (e.g. alternative pronunciation, speech rhythm, plot, or graph).
Suggestion	it suggests methods and strategies towards the correct answer or solution.
Similarity	it presents a similar question and its correct answer.
Specialization	it presents an example, or a special case of the question with its correct answer.
Generalization	it presents a generalization of the question (e.g. law, principle, or theorem) with its correct answer.
Substitute	it substitutes the current question and/or answers with similar ones.

After-the-Answer Cognitive Feedback	
Verification	it verifies and confirms whether her answer is correct or wrong.
Correction	it corrects the wrong answer and provides the correct answer
Comment	it comments on the quality of the answer, on how close or faraway it is from the perfect.
Explanation	it explains why the answer is correct or wrong.
Elaboration	it extensively analyzes and elaborates on the knowledge that is related to the question.
Recommendation	it recommends to the learner additional educational material and activities.
Ranking	it ranks and orders the answers with respect to their quality, e.g. best answer, second best answer etc.
Equivalent	it presents equivalent cases.
Application	it applies the question and answer to practical, real life cases.
Extension	it extends the question and answer to further knowledge.
Comparison	it compares the learner's answer to those of other learners.
Alerting	it alerts the learner about misconceptions, wrong ideas and false beliefs she may have.
Progress	it informs the learner on her progress (e.g. plot, trail) about her score per question, difficulty level per question, ability per question, time per question, etc.

Pre-Answer emotional feedback	
Enhancement	it enhances and develops positive emotions.
Prevention	it prevents and avoids the building of negative emotions.
Weakening	it weakens and alleviates negative emotions.
Transformation	it transforms negative emotions to positive ones.
Inspiration	it inspires and excites the learner's enthusiasm and curiosity.
Entertainment	it entertains and amuses the learner.
Compassion	it shows compassion and understanding to the learner.
Relaxation	it relaxes the learner's anxiety and stress.

After-the-Answer emotional feedback	
Enhancement	it enhances and develops positive emotions.
Prevention	it prevents and avoids the building of negative emotions.
Weakening	it weakens and alleviates negative emotions.
Transformation	it transforms negative emotions to positive ones.
Calm	it calms and cools down the learner.
Sympathy	it sympathizes and excuses the learner.
Hope	it develops the learner's hope and optimism.
Praise	it praises, congratulates and honors the learner
Criticism	it criticizes the learner.

Pre-Answer conational feedback	
Enhancement	it enhances and develops positive attitude and conation.
Prevention	it prevents and avoids the building of negative attitude and conation.
Weakening	it weakens and alleviates negative attitude and conation.
Transformation	it transforms negative attitude and conation to positive ones.
Awareness	it helps the learner become self-aware and self-conscious.
Attraction	it attracts the learner's attention and interest.
Challenge	it stimulates and challenges the learner.
Motivation	it motivates the learner.
Encouragement	it encourages the learner.
Determination	it develops the learner's determination, will and intention.

After-the-Answer conational feedback	
Enhancement	it enhances and develops positive attitude and conation.
Prevention	it prevents and avoids the building of negative attitude and conation.
Weakening	it weakens and alleviates negative attitude and conation.
Transformation	it transforms negative attitude and conation to positive ones.
Reassurance	it reassures the learner that she is doing well and is on the right track.
Confidence	it develops the learner's confidence and self-esteem.
Commitment	it develops the learner's commitment and dedication.
Reward	it rewards the learner
Punishment	it punishes the learner.

3 AFE Criteria

The CAT system continually monitors and senses the learner. Then it estimates and diagnoses her current state. The feedback is based on the learner's current state and educational situation. It is presented to the learner on her demand or automatically by the CAT system at appropriate instances. Either the learner or the CAT system has control over the feedback. It may reward or punish the learner. It may support her at the cognitive, emotional or conational dimension. The next table presents the criteria for evaluating the adaptive feedback.

3.1 Sensing

The adaptive feedback depends on how well the CAT system senses the learner's state (physical, cognitive, emotional and conational). So, it is important that there is a variety of high quality sensors. These sensors should accurately and continually sense various parameters of the learner.

3.2 Cause detection

It is important that the sensors accurately detect and recognize the cause and reason for which a learner transfers from a state to a new state.

AFE Criteria
Sensing of learner's state
Cause Detection
Recognition & Diagnosis of learner's state
Adaptation & Personalization
Control
Activation
Responsiveness
Frequency
Reinforcement Method
Mind Dimension
Type
Area
Content
Easy to Understand & to Use, Clear
Suitability
Appropriate Quantity
Simplicity
Relevance
Correctness, & Accuracy
Consistency & Uniformity
Presentation
Media
Language & Accessibility
Fidelity
Appropriateness
Aesthetics
Consistency
Navigation
Orientation
Duration
Lifetime
Results
Effective, Useful & Helpful
Increase Satisfaction
Develop Self-Awareness
Activate Knowledge & Abilities
Increase Performance & Achievements
Enhance Strengths
Reduce Weaknesses
Prevent Failures
Correct Misconceptions
Overcome Inefficiencies
Min overhead, No distraction & Min delay
Connectivity, Reusability, Compatibility & Exportability
Autonomy
Security, Privacy & Confidentiality
Cost

For example, the learner may become angry when she does not agree with the CAT system about the correctness of her answer.

3.3 Recognition & Diagnosis

After the CAT system detects the cause that triggered the learner's new state, it is important to accurately recognize and diagnose this new state. For the previous example, the new learner's state includes that she is angry and irritated.

3.4 Adaptation & Personalization

All feedback parameters would be adapted to the learner's current state. So, the feedback would be personalized and tailored to the learner's current state. It is important that the adaptation promotes the overall learning quality.

3.5 Control

The feedback would be invoked and controlled by a person (e.g. learner, teacher), automatically by the system, or cooperatively by the system and a person. For example, a hint appears on learner's demand. Or, the learner controls the amusement duration. Or, the system proposes a set of alternatives and the learner selects one. The feedback control should be based on the learner's state and educational situation. For some learner's states, it would be better that the learner may have control over the feedback. For other learner's states, it would be preferable that the system has control over the feedback. It is important that the assignment of the feedback control develops the overall learning quality.

3.6 Activation

The feedback may be presented at scheduled times (e.g. after every answer) or whenever the controller (e.g. learner, system) decides. Also, it may appear definitively (deterministically) or probabilistically. In the latter case, it appears with an activation probability. So, other times it is presented and other times not. The feedback activation should be based on the learner's state and educational situation. For some learner's states, it would be better that it is scheduled. For other learner's states, it would be preferable that it is dynamic. It is important that it is activated at the right time to satisfy the overall learning quality.

3.7 Responsiveness

The responsiveness and timeliness of the feedback is also important. The feedback should appear at the proper time. For some cases, it would be more appropriate that the controller anticipates and forecasts the next learner's state and activates the feedback before a specific learner's state. For other cases, it would be more appropriate that the feedback appears just after a specific learner's state is happening. Finally, for other cases, it would be more appropriate if the feedback is delayed for some time after a specific learner's state happened.

3.8 Frequency

The frequency of the feedback appearance is also important. The feedback should appear at the right frequency; not too often, not too rare. The feedback frequency should be based on the learner's state and educational situation.

3.9. Reinforcement Method

The reinforcement method adopted should promote the overall learning quality. The feedback would either reward the learner, or punish the learner, or even be neutral. It is important that the right reinforcement method is employed for every learner's state and educational situation.

3.10 Mind Dimension

The feedback would support the learner either at the cognitive dimension, or the emotional dimension, or the conational dimension. It is important that the right mind dimension is used to improve the overall learning quality.

3.11 Type

After deciding the mind dimension for the feedback, it is important to apply the appropriate feedback type (see previous section 2).

3.12 Area

The feedback would be used to support the learner not only on answering the questions, but also on using the user interface and the CAT system, on navigating and orientating, on communicating and collaborating with others, etc. It is important that the feedback support the learner in a variety of areas in order to improve the overall learning quality.

3.13 Content

The content of the feedback is extremely important. It should be clear and easy to understand and use. Obviously, it should be correct and accurate. It should be meaningful and rational. It should be suitable for the specific learner's state and educational situation. So, its quantity, its level of simplicity, and its relevance should be appropriate for the specific learner's state and educational situation. It should be consistent and uniform. That means similar feedback should appear for similar learner's state and educational situation.

3.14 Presentation

The presentation of the feedback is extremely important. The feedback should use media (e.g. text, voice, graphs, pictures, and video) and format that are appropriate for the specific learner's state and educational situation. They should be at the right quantity, mix and positioning. For example, some learners may prefer only visual feedback, while others may prefer a mix of visual and audio feedback. They should be used in a consistent way. For example, the feedback should employ a stable way of using the keys, colors, menus, forms, etc. The aesthetics and the media fidelity are also important. Finally, the feedback should support a variety of languages and access methods to fairly support all people. None should feel discriminating.

3.15 Navigation

The navigation of the feedback should be easy, intuitive and simple. There should be a variety of feedback navigation methods. However, the feedback navigation should be based on the learner's state and educational situation. In addition, it should be consistent.

3.16 Orientation

The orientation of the feedback should be easy and useful. There should be a variety of feedback orientation methods. However, the feedback orientation should be based on the learner's state and educational situation. The feedback orientation should be at the right quantity. In addition, it should be consistent.

3.17 Duration

The learner may be supported by feedback during the whole duration of the test or during some time intervals (e.g. during the first 10 minutes). This feedback duration should be appropriate for the specific learner's state and educational situation.

3.18 Lifetime

The feedback should have the appropriate lifetime for the specific learner's state and educational situation. The feedback lifetime would be controlled by the learner or by the system. For some learner's states it would be short, while for others it would be long. Similarly, it would be fixed or dynamic.

3.19 Results

The feedback should result in improvement of the learner's performance, satisfaction, self-awareness and competences. The feedback should be effective so that the learning objectives and the target educational outcomes are achieved. It should be useful and helpful for the learner. It should enhance the learner's strengths, reduce her weaknesses, prevent her failures, correct her misconceptions and overcome her inefficiencies. It should also create minimum overhead and delay, as well no distraction to the learner.

3.20 Connectivity, Interoperability, Reusability, Compatibility & Exportability
The connectivity of the feedback to other resources and systems is also very important. The feedback should be compatible and comply to standards. It should be easily exported and reused in various learners' states, educational situations and other educational systems.

3.21 Autonomy
The feedback should be autonomous. It should efficiently operate without need for extra hardware and software.

3.21 Security, Privacy & Confidentiality
The security of the feedback is also important. Only authorized persons should read or write the feedback destined to a specific learner. The privacy and confidentiality of the feedback is extremely crucial. For example, it would be unethical that an unauthorized person monitors and observes the learner's performance or emotions, or even supply unauthorized feedback.

3.22 Cost
Finally, all the above feedback parameters should be achieved at an affordable cost. The cost should be related to the results. For example, high learner's performance may excuse high feedback cost.

4 Conclusion
This paper analyzes the adaptive feedback in CAT systems. The adaptive feedback is based on the learner's state (cognitive, emotional and conational) and the educational situation. It supports the learner to answer correctly the test questions and improve her knowledge and abilities. It also supports the learner emotionally and motivationally. Then, the paper presents AFE, an evaluation framework for effective adaptive feedback in CAT systems. It includes twenty two evaluation criteria. Analysts, designers, developers and evaluators of CAT systems may find AFE useful to make appropriate decisions.

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