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Personalized Feedback in CAT

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Abstract: - Feedback can be generated by Computer Adaptive Testing (CAT) systems to support and enhance learning, self-awareness, self-regulation, and self-improvement. Feedback is more effective when it is personalized to each learner's state. So, there is the question what feedback attributes would be adapted to each learner's state in order to provide personalized feedback. This paper presents the feedback attributes that would be adapted to the learner's state. In CAT, feedback would be generated before and after a question, problem or task is presented to the learner. This paper proposes various pre-question and after-the-question feedback types. These feedback types would be personalized to specific mind states of the learner. These include cognitive, emotional and conational feedback types. The proposed feedback attributes and personalized feedback types would be useful for analysts, designers, developers and evaluators of CAT systems to make appropriate decisions.

Key-Words: - Adaptive feedback, adaptive testing, evaluation, personalized feedback.

1 Introduction

While educators accept the importance of feedback, most computer based educational systems underutilize it. Feedback would be integrated into CAT (Computer Adaptive Testing) systems to support the learner to increase her knowledge, abilities, competences and strengths, to prevent her failures and mistakes, to correct her misconceptions and errors, and decrease her inefficiencies and weaknesses. It can encourage her and promote her active participation. It can also help her to increase her self-awareness, motivation, self-esteem, confidence, and self-regulation. A CAT system presents questions to the learner on the basis of her response to previous questions [1, 2, 3]. The CAT system estimates the learner's ability level, and presents questions around to her estimated ability level. 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].

To be more effective, the feedback would be personalized based on the learner's current state. The most benefits come when each learner receives individualized feedback most suited to her needs. It may support the learner at the cognitive, emotional or conational dimension. It 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.

Previous research on feedback [6, 7] analyzes the cognitive feedback. The cognitive feedback is composed of two elements: 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 presents the various attribute of feedback that would be adapted to the learner's current state. It also proposes various feedback types that would be presented to the learner based on her current cognitive, emotional and conational state. Section 2 presents the phases of personalized feedback. Section 3 presents the attributes that would be adapted for personalized feedback. Section 4 presents various personalized feedback types. Finally, Section 5 presents the conclusions.

2 Phases of Personalized Feedback

The CAT system continually monitors, senses and measures the learner. It detects any changes into the learner's state. Then it estimates and diagnoses her current state. The personalized feedback is based on the learner's current state. The various feedback attributes are adapted to the learner's current state. Finally, the result of the feedback is evaluated to determine its success. So, the phases of the personalized feedback are the following:

1. Sensing & Measurement of the learner
2. Cause Detection
3. Recognition & Diagnosis
4. Adaptation & Personalization
5. Feedback Application
6. Feedback Management
7. Feedback Termination
8. Evaluation

2.1 Sensing & Measurement of the learner

The personalized feedback depends on how well the CAT system senses and measures 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.

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

2.3 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.

2.4 Feedback Adaptation & Personalization

Various attributes of the 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. The next Section 3 describes the feedback attributes that would be adapted to the learner's current state.

2.5 Feedback Application

After the feedback is personalized to the learner's current state, it is applied to the learner. For example, an advice is presented visually or verbally to her.

2.6 Feedback Management

The feedback would exist for some time period. During this time period the CAT system records various parameters and adjusts the level of the feedback attributes.

2.7 Feedback Termination

At some instant, the feedback is terminated either because its lifetime expired or an action happened or for some other reason.

2.8 Evaluation

Finally, it is important to evaluate the results of the personalized feedback. It is important that the personalized feedback promotes the overall learning quality. This evaluation would be done with respect to learner's progress, to other learners, or to standards.

3 Attributes of Personalized Feedback

The feedback is described using multiple attributes (Figure 1). For example, the feedback control is one such attribute. The feedback may be 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.

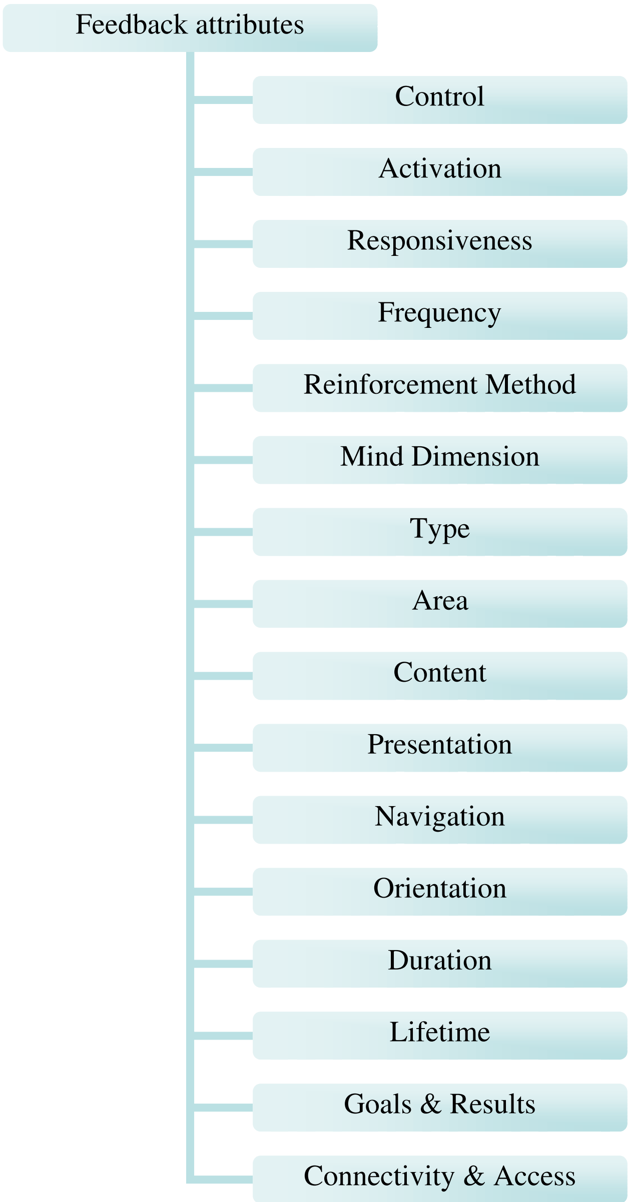

Figure 1: Feedback attributes.

3.1 Control

The feedback control would be personalized to the specific learner's state. Depending on the learner's state, 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. 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.

3.2 Activation

The feedback activation would be personalized to the specific learner's state. For some learners, it would be preferable that the feedback is presented at scheduled times (e.g. after every answer), while for others whenever the controller (e.g. learner, system) decides. Also, for some learners it would be better that it appears definitively (deterministically), while for others probabilistically. In the latter case, it appears with an activation probability. So, other times it is presented and other times not. It is important that it is activated at the right time to satisfy the overall learning quality.

3.3 Responsiveness & Timeliness

The feedback responsiveness and timeliness would be personalized to the specific learner's state. The feedback should appear at the proper time for the specific learner's state. 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.

3.4 Frequency

The feedback frequency would be personalized to the specific learner's state. The feedback should appear at the right frequency; not too often, not too rare. For example, if a learner successfully proceeds through the test, then there is no need for interrupting her with feedback.

3.5 Reinforcement Method

The reinforcement method adopted by the feedback would be personalized to the specific learner's state. The feedback would either reward the learner, or punish her, or even be neutral. It is important that the right reinforcement method is employed for every learner's state in order to promote learning and achievements.

3.6 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 based on the learner's state to improve the overall learning quality. For example, a learner may be so frustrated that she cannot even read or listen to any advice. So, feedback at the cognitive dimension would be useless. Or, she may need a Specialization (example) to take ideas on how to approach the question.

3.7 Type
The feedback type would be personalized to the specific learner's state. After deciding the mind dimension for the feedback, it is important to apply the appropriate feedback type (see next Section 4). For example, the learner may need a Hint to make the first step in answering the question.

3.8 Area
The feedback may support the learner on several areas. It may help 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. Depending on the learner's current state, feedback on the appropriate area may support the learner.

3.9 Content
The content of the feedback is extremely important. It would be personalized to the specific learner's state. The following sub-attributes are related to the content: i) Quantity & Amount, ii) Simplicity, and iii) Relevance & Proximity (Figure 2). For some learners the feedback would be short and brief, while for others it would be lengthy and detailed. For some learners it would be presented in a simple way, while for others in a complex and elaborated way with difficult meanings and words. Finally, for some learners it would be specific, precise and exactly to the point, while for others general, approximate and roundabout.

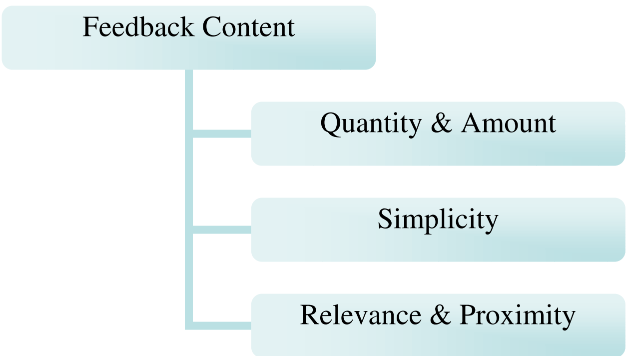

Figure 2: Feedback Content sub-attributes

3.10 Presentation
The feedback presentation should be personalized to the specific learner's state. The following sub-attributes are related to the presentation: i) Media, ii) Layout & Format, and iii) Language & Accessibility (Figure 3). For some learners, visual presentation may be more appropriate, while for others audio. Furthermore, for some others a mix of media at the right proportion may be more appropriate. The layout & the format would be also adapted to the learner's state. For example, for some learners the font size may be larger than for others. Or, the speech tone would be tailored to each learner. Finally, the feedback should support a variety of languages and access methods to fairly support all people. None should feel discriminating.

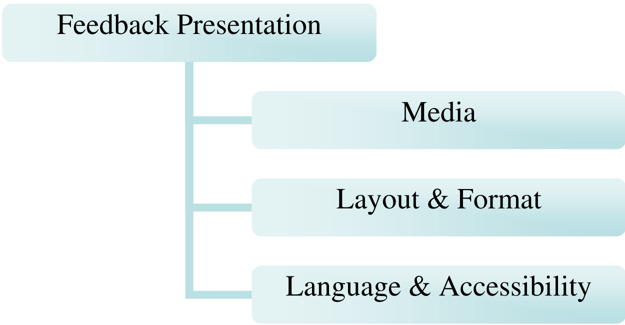

Figure 3: Feedback Presentation sub-attributes.

3.11 Navigation
The feedback navigation would be personalized to the specific learner's state. For example, many feedback navigation options may be presented to some learners, while limited ones to others.

3.12 Orientation
The feedback orientation would be personalized to the specific learner's state. For example, many feedback orientation options may be presented to some learners, while limited ones to others.

3.13 Duration
The learner would 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.

3.14 Lifetime
The feedback lifetime would be personalized to the specific learner's state. It 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.

3.15 Goals & Results

Depending on the learner's state, the feedback would aim at different goals and results. Thus, the feedback goals and results would be personalized to the specific learner's state. The feedback would aim at the following sub-attributes goals and results: i) Increase Learning, ii) Increase Satisfaction, iii) Increase Performance & Achievements, iv) Increase Participation, v) Enhance Strengths, vi) Reduce Weaknesses, vii) Prevent Failures, viii) Correct Misconceptions, ix) Overcome Inefficiencies, and x) Develop Self-Awareness (Figure 4). Abilities, such as critical thinking, decision-making, leadership, innovating, motivation, self-esteem, confidence, self-regulation etc. are included into the Strengths.

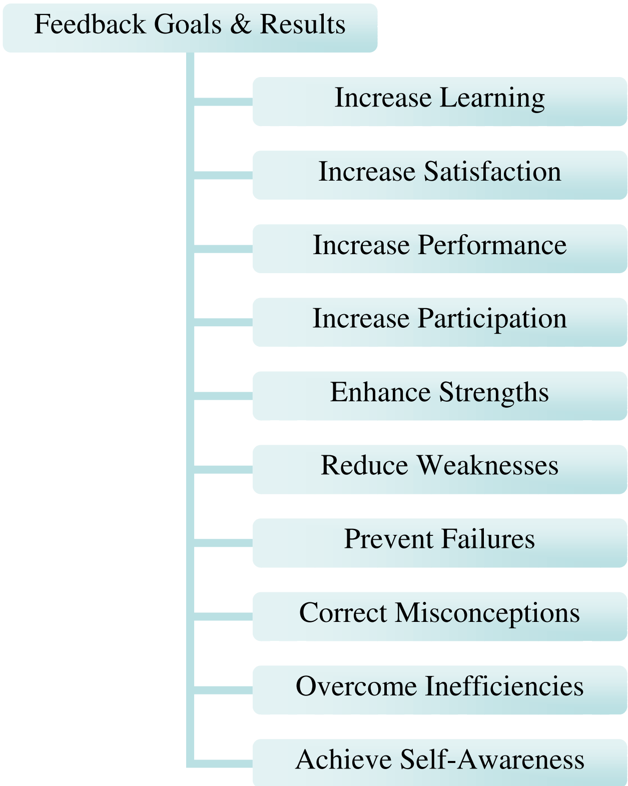

Figure 4: Feedback Goals & Results.

3.16 Connectivity & Access

The feedback connectivity to other resources and systems would be personalized to the specific learner's state. The feedback may provide open access to resources for some learners, while keeping them restricted for others.

4 Adaptive Feedback types

The feedback may support the learner at the cognitive, emotional or conational mind dimension. Depending on the learner's state, different feedback type may support her. Next, we present various feedback types. They can be presented to the learner before she answers every question, problem or task (Figure 5), and after she answers it (Figure 6).

4.1 Pre-Answer Cognitive Feedback

1. *Guidance*: it guides the learner on how to use the CAT system in order to answer the question.
2. *Availability-Restrictions*: it informs the learner on the currently available and restricted resources (e.g. email, search engine, Web, chat, FAQ, software), and actions.
3. *Orientation*: it orientates the learner about the question, i.e. its corresponding subject, its goal, the ability to be tested, its importance, its difficulty level, its grading criteria, its possible scores, its possible hints, its time, etc.
4. *Organization*: it helps the learner to organize her effort, energy and time to answer correctly the question.
5. *Warning*: it warns about common errors made by learners due to misconceptions or carelessness.
6. *Hint*: it provides extra relevant knowledge on the question, or a first step towards the correct answer.
7. *Alternative*: it presents to the learner the question in alternative media and format (e.g. alternative pronunciation, speech rhythm, plot, or graph).
8. *Suggestion*: it suggests methods and strategies towards the correct answer or solution.
9. *Similarity*: it presents a similar question and its correct answer.
10. *Specialization*: it presents an example, an application, or a special case of the question with its correct answer.
11. *Generalization*: it presents a generalization of the question (e.g. law, principle, or theorem) with its correct answer. Or, it presents the main ideas and concepts that are related to the question.
12. *Substitute*: it substitutes the current question and/or answers with similar ones.

4.2 Pre-Answer emotional feedback

1. *Emotion Enhancement*: it enhances and develops positive emotions.
2. *Emotion Prevention*: it prevents and avoids the building of negative emotions.
3. *Emotion Weakening*: it weakens and alleviates negative emotions.
4. *Emotion Transformation*: it transforms negative emotions to positive ones.
5. *Inspiration*: it inspires and excites the learner's enthusiasm and curiosity.
6. *Entertainment*: it entertains and amuses the learner.

7. *Compassion*: it shows compassion and understanding to the learner.
8. *Relaxation*: it relaxes the learner's anxiety and stress.

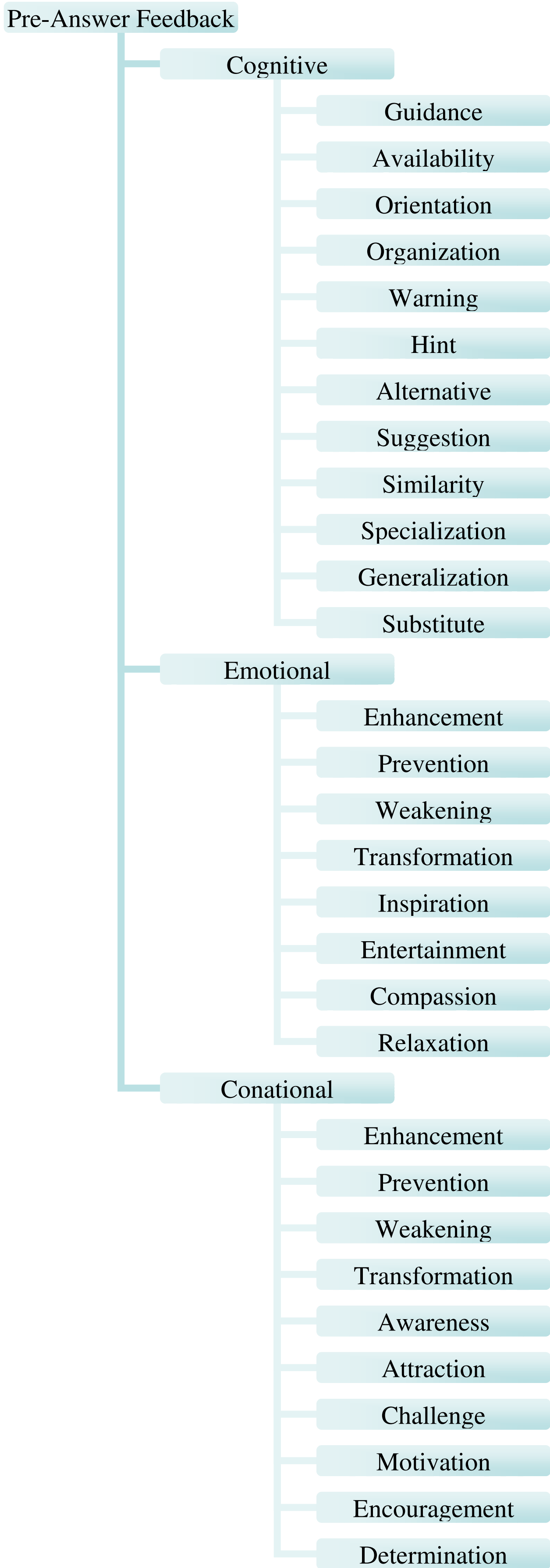

Figure 5: Pre-Answer Feedback.

4.3 Pre-Answer conational feedback

1. *Conation Enhancement*: it enhances and develops positive attitude and conation.
2. *Conation Prevention*: it prevents and avoids the building of negative attitude and conation.
3. *Conation Weakening*: it weakens and alleviates negative attitude and conation.
4. *Conation Transformation*: it transforms negative attitude and conation to positive ones.
5. *Awareness*: it helps the learner become self-aware and self-conscious.
6. *Attraction*: it attracts the learner's attention and interest.
7. *Challenge*: it stimulates and challenges the learner.
8. *Motivation*: it motivates the learner.
9. *Encouragement*: it encourages the learner.
10. *Determination*: it develops the learner's determination, will and intention.

4.4 After-the-Answer Cognitive Feedback

1. *Verification*: it verifies and confirms whether her answer is correct or wrong.
2. *Correction*: it corrects the wrong answer and provides the correct answer.
3. *Comment*: it comments on the quality of the answer, on how close or faraway it is from the perfect.
4. *Explanation*: it explains why the answer is correct or wrong.
5. *Elaboration*: it extensively analyzes and elaborates on the knowledge that is related to the question.
6. *Recommendation*: it recommends to the learner additional educational material and activities.
7. *Ranking*: it ranks and orders the answers with respect to their quality, e.g. best answer, second best answer etc.
8. *Equivalent*: it presents equivalent cases.
9. *Application*: it applies the question and answer to practical, real life cases.
10. *Extension*: it extends the question and answer to further knowledge and concepts.
11. *Comparison*: it compares the learner's answer to those of other learners.
12. *Alerting*: it alerts the learner about misconceptions, wrong ideas and false beliefs she may have.
13. *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.
14. *Rhetorical Question*: it asks an additional question to trigger reflection, e.g. what if …

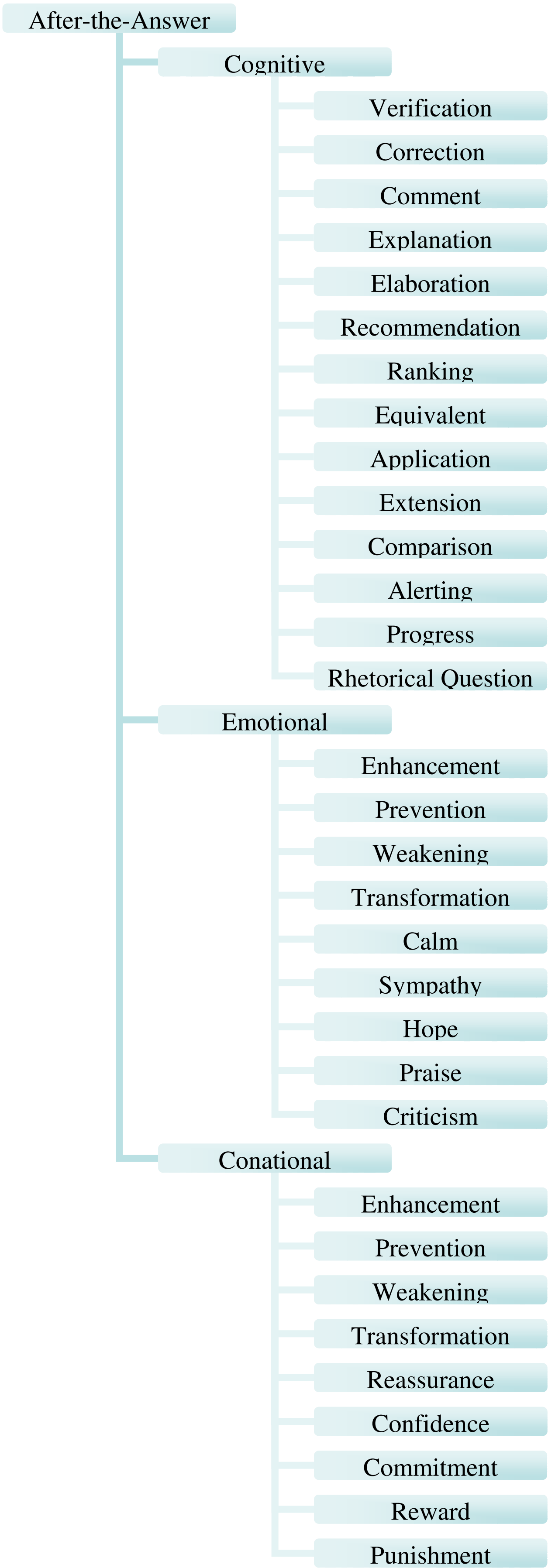

Figure 6: After-the-Answer Feedback.

4.5 After-the-Answer emotional feedback

1. *Emotion Enhancement*: it enhances and develops positive emotions.
2. *Emotion Prevention*: it prevents and avoids the building of negative emotions.
3. *Emotion Weakening*: it weakens and alleviates negative emotions.
4. *Emotion Transformation*: it transforms negative emotions to positive ones.
5. *Calm*: it calms and cools down the learner.
6. *Sympathy*: it sympathizes and excuses the learner.
7. *Hope*: it develops the learner's hope and optimism.
8. *Praise*: it praises, congratulates and honors the learner.
9. *Criticism*: it criticizes the learner.

4.6 After-the-Answer conational feedback

1. *Conation Enhancement*: it enhances and develops positive attitude and conation.
2. *Conation Prevention*: it prevents and avoids the building of negative attitude and conation.
3. *Conation Weakening*: it weakens and alleviates negative attitude and conation.
4. *Conation Transformation*: it transforms negative attitude and conation to positive ones.
5. *Reassurance*: it reassures the learner that she is doing well and she is on the right track.
6. *Confidence*: it develops the learner's confidence and self-esteem.
7. *Commitment*: it develops the learner's commitment and dedication.
8. *Reward*: it rewards the learner.
9. *Punishment*: it punishes the learner.

5 Conclusions

This paper presents the phases of using personalized feedback in CAT. Then, it presents the feedback attributes that would be adapted to the learner's current state. Finally, it proposes pre-answer and after-the-answer personalized feedback types. They would be based on the cognitive, emotional and conational states. Analysts, designers and developers of personalized feedback in CAT systems would adapt these feedback attributes to the learner's current state. They can also use the proposed feedback types to provide personalized cognitive, emotional and conational feedback to the learner. Evaluators of CAT systems may also use this paper to select the appropriate CAT system to satisfy their needs.

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