



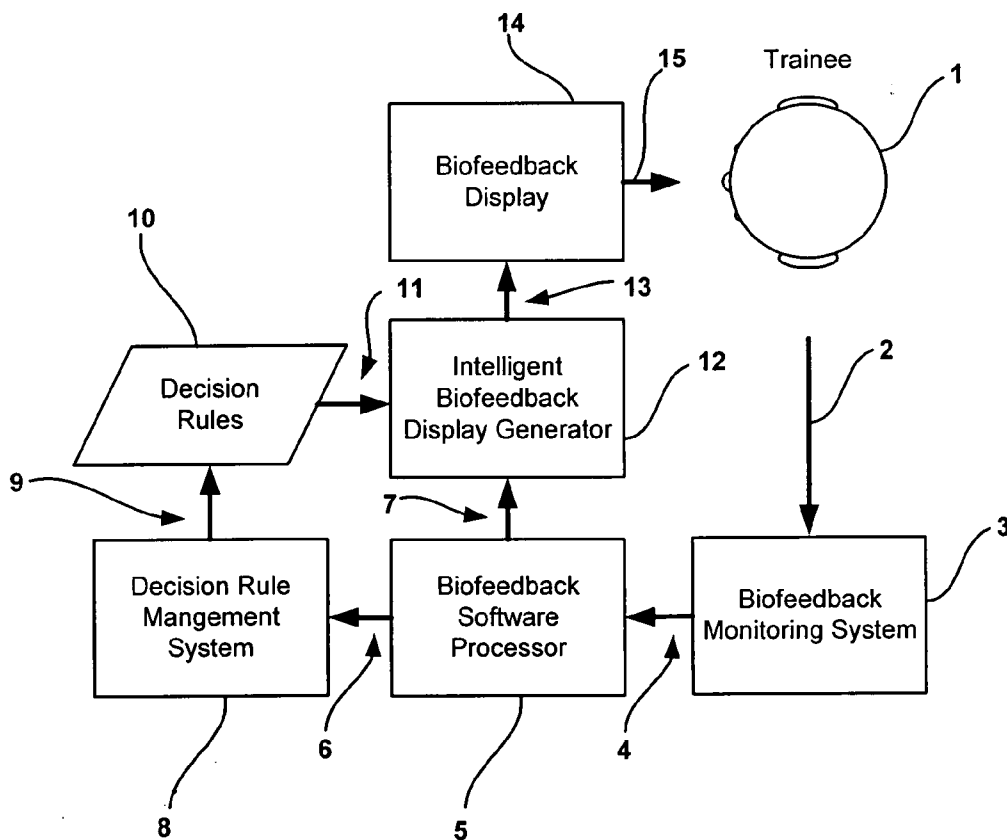
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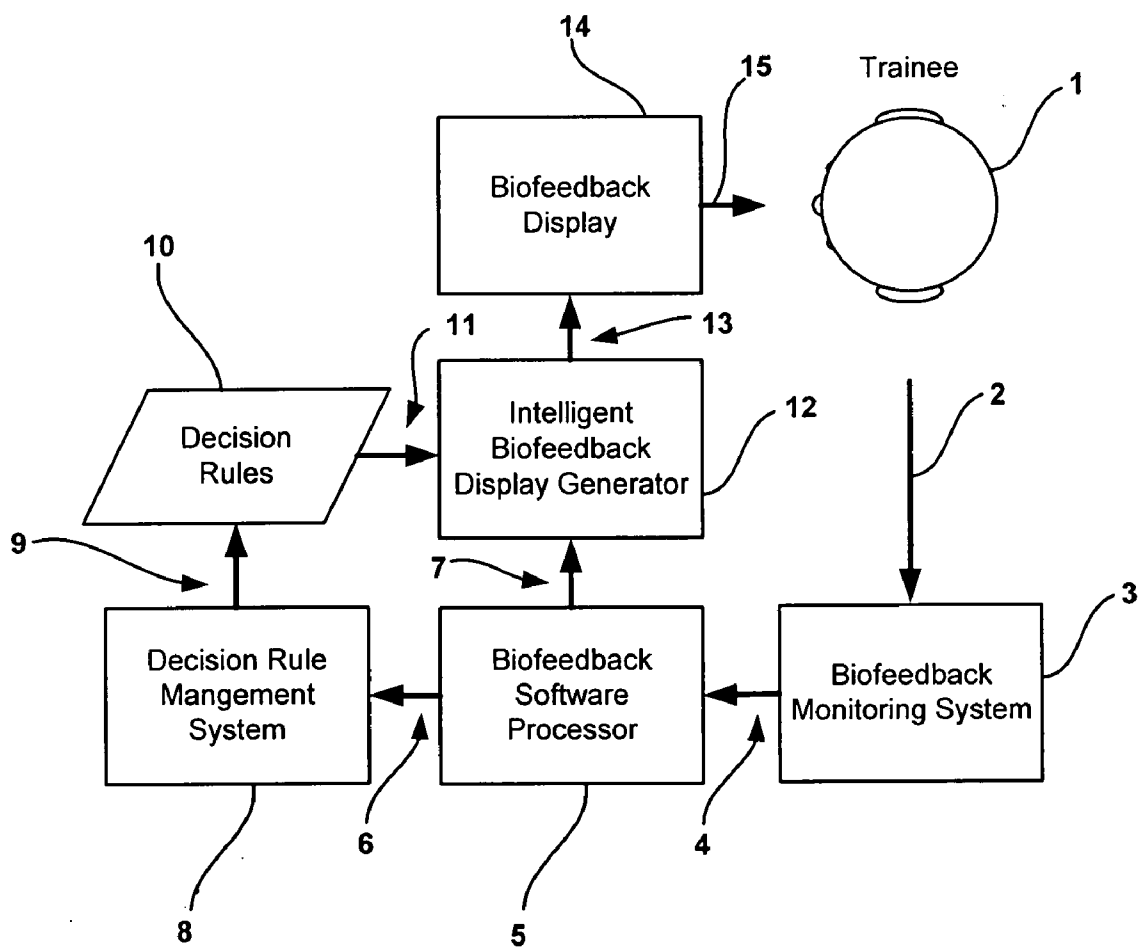
(19) **United States**(12) **Patent Application Publication**
Collura et al.(10) **Pub. No.: US 2007/0197292 A1**(43) **Pub. Date: Aug. 23, 2007**(54) **SYSTEM AND METHOD FOR
INCORPORATING ARTIFICIAL
INTELLIGENCE INTO A BIOFEEDBACK
TRAINING SYSTEM****Publication Classification**(51) **Int. Cl.**
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CLEVELAND, OH 44114(21) **Appl. No.: 11/709,107**(22) **Filed: Feb. 21, 2007****Related U.S. Application Data**(60) **Provisional application No. 60/774,593, filed on Feb.**
21, 2006.(57) **ABSTRACT**

A biofeedback training system and method which utilizes biological signals from a trainee to influence actions and events in an activity or game displayed to the trainee. A level of intelligence in a displayed activity or game is used as a biofeedback variable. Decision-making rules or other abilities within an embedded game player are introduced and controlled as additional types of biofeedback variable, and represent awards in a training process. The methods and systems can be applied to any activity or game that includes goal-seeking behavior and that can be configured for automatic play by goal-oriented rules. The action and content of game-like biofeedback displays may be influenced or dictated by biological signals from a trainee viewing the display.

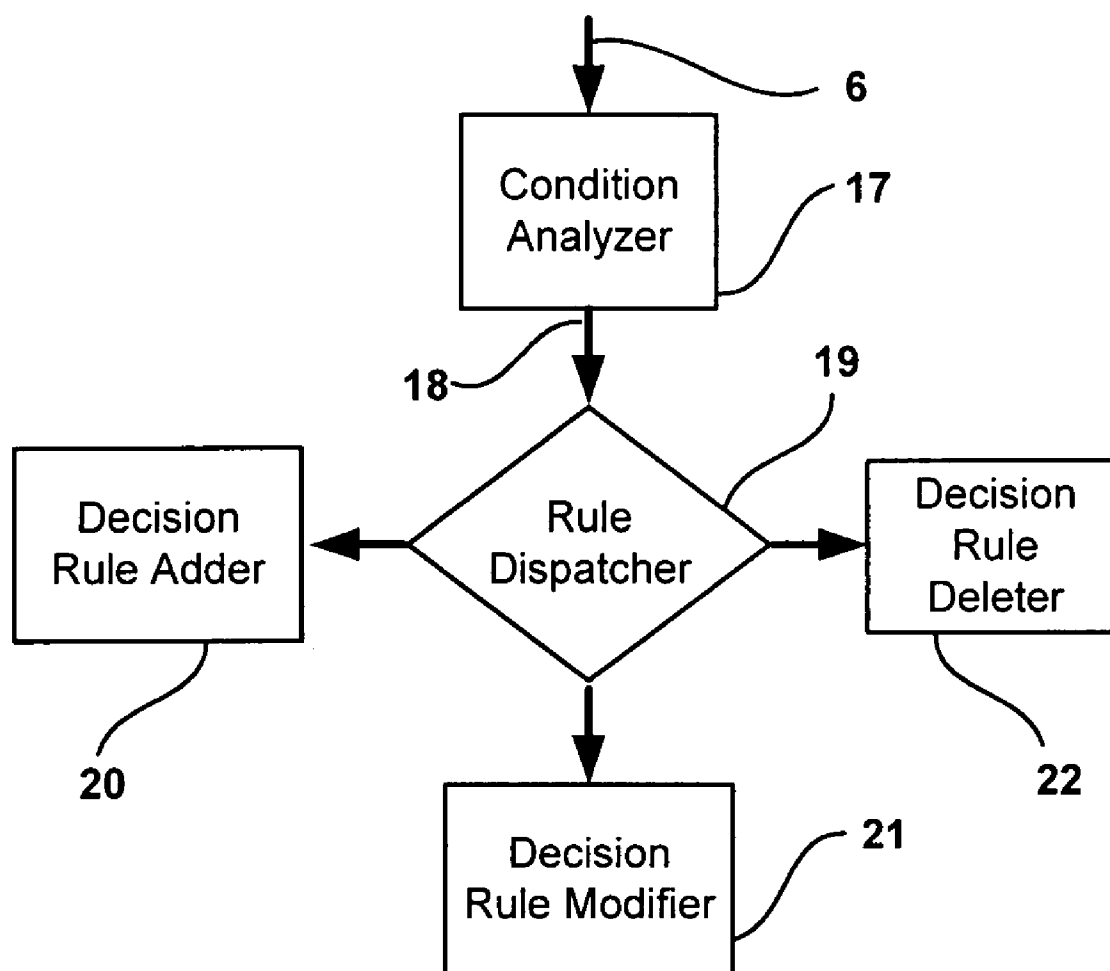
**Biofeedback Training System with Artificial Intelligence**



Biofeedback Training System with Artificial Intelligence

FIGURE 1

(from Biofeedback Software Processor 5)



Decision Rule Management System

FIGURE 2

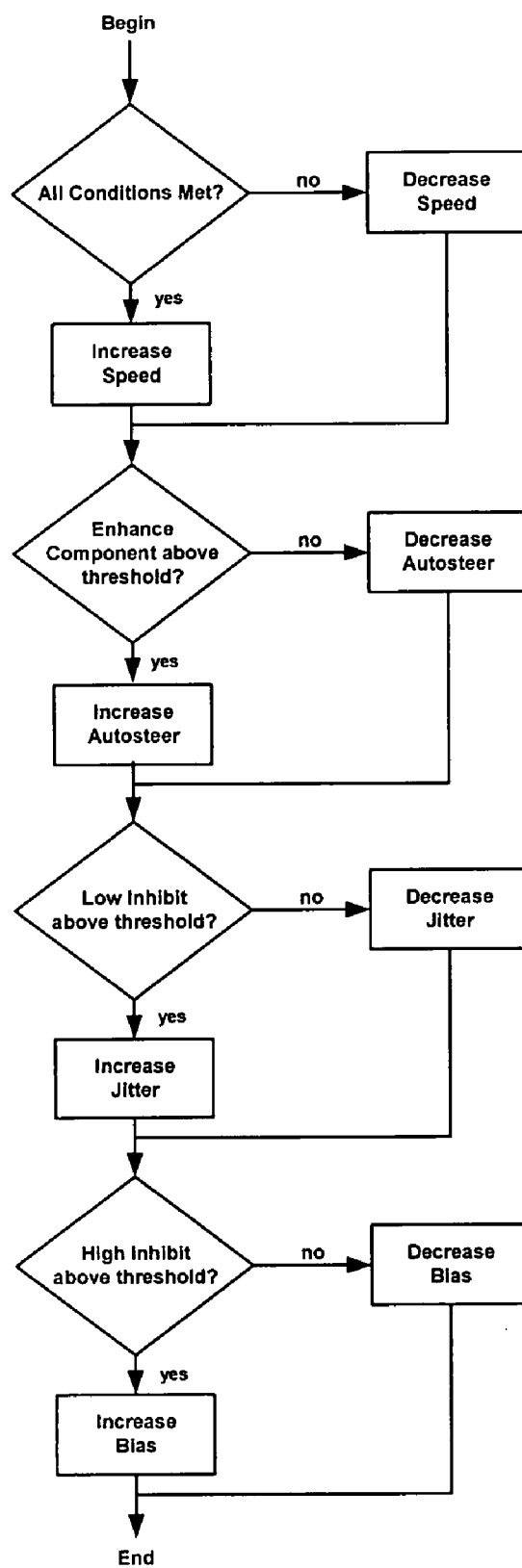


FIGURE 3

SYSTEM AND METHOD FOR INCORPORATING ARTIFICIAL INTELLIGENCE INTO A BIOFEEDBACK TRAINING SYSTEM

RELATED APPLICATION

[0001] This application is a conversion of U.S. Provisional Patent Application No. 60/774,593, filed Feb. 21, 2006.

FIELD OF THE INVENTION

[0002] The invention is in the general field of biofeedback and systems and methods for generating and controlling biofeedback stimuli.

BACKGROUND OF THE INVENTION

[0003] Biofeedback and neurofeedback function by virtue of conditioning, either classical conditioning, operant conditioning, or combinations thereof. Classical conditioning occurs when an organism is presented with two events that are conjoined, such as the case of Pavlov who conditioned dogs to respond with a digestive response (salivation) that was associated with the ringing of a bell. Operant conditioning occurs when an organism learns that one or more of their behaviors (including producing biological signals) consistently results in an external event (such as the ringing of a bell). In both cases, the organism learns the association, and the result is learning. Biofeedback and neurofeedback training are thus able to teach the trainee to produce, inhibit, or modify biological signals, and which learning is accomplished by the presenting of rewards. Such rewards can be provided by automatic equipment or computers, that present information in real time, in response to the trainee's biological activity.

[0004] Practitioners often use game-like displays in biofeedback and neurofeedback systems. Such games provide interest value and informative real-time feedback for training purposes. For example, automated or computerized games such as watching the running of a maze, catching a ball, shooting baskets, or other activities can be used as part of a feedback output system, providing visual, auditory, or vibrotactile feedback. Generally, such games are rather simple, providing simple progress reporting, with the possibility of quantitative output such as "how much" or "how fast", and so on. Such games tend to have consistent difficulty and behavior, limiting the amount of possible improvement, limiting interest value, limiting novelty, and limiting the ability to provide a higher level of information to the trainee. Such high level information may include the rate of improvement, summary information regarding training history, indication of training progress, information regarding the occurrence of "inhibit" phenomena, and other quantitative and qualitative changes signaling relevant changes in the training variables and progress.

SUMMARY OF THE INVENTION

[0005] In this invention, the feedback game is endowed with intelligence in the form of goal-seeking and decision-making behavior, providing an additional element of context, activity, and quality in the feedback. In this invention, the level of intelligence evident in the game is controlled ("modulated") as an additional dimension of the training feedback, providing a deeper level of information and guidance.

[0006] For example, in a maze game, it is typical to construct a feedback system in which the maze is always run the same way, either by following the identical path, or by always using the same (generally simple) rules for running the maze. Thus, the only form of feedback may consist of stop/go information, as the game progresses. This is useful in providing interest value, but lacking lasting or deeper information of potential value to the trainee and to the feedback administrator. There exists a need to provide additional information, for purposes of enhanced training, as well as for assessment.

[0007] In biofeedback and neurofeedback, it is possible to modulate games that the trainee plays, as described for example in U.S. Pat. No. 6,450,820 to A. Pope et. al. Such interaction requires motor movements and attention, and can subvert the goal of the training, which may include stillness and relaxation, rather than activation. Such systems also may introduce muscle and other artifacts, as a result of the required playing activities. Therefore, games that "play themselves" are of specific value in biofeedback and neurofeedback, in providing an informative and engaging display, that nonetheless allows the trainee to influence the progress and success of the game display. The trainee watches the progress of the game, and watches the "player" move and act toward the goal of the game, without having to use keyboard or joystick controls, for example, to control the game progress. In other words, the level of intelligence in the game is used as a biofeedback variable.

[0008] In this invention, the trainee does not have to interact with the game in any manner other than by producing the biological signals. This allows the trainee to remain still, and to focus their attention on the game, as the only means or method necessary to control the game, as well as to modulate the behavior of the game. If the game has perceptible hindrances or shortcomings, then these are in principle under the possible control of the trainee, who can influence the intelligence and efficiency evident in the game, by addressing their ability to make progress in the biofeedback training.

[0009] Humans are able to perceive and interpret complex information such as high-level behavior of a system, and to use that information in the pursuit of learning. Humans are also prone to become bored with repetitive or constant experience, and seek novelty and improvement. Such novelty and improvement constitute powerful rewards, and a system that incorporates such novelty and improvement will benefit by providing additional interest, incentive, and information to the trainee. The result is the ability to perform the training with increased interest, with increased perception and understanding, and for longer periods of time. An additional result is the ability to perceive qualitative changes (improvement or degradation) either within a session or across sessions, as an additional index of progress.

[0010] In this invention, the existence of decision-making rules and other abilities within the embedded game player are introduced and controlled as additional types of feedback variables, in addition to the traditional "stop/go" or "faster/slower" modulation in the feedback. Such abilities would typically be controlled in a gradual fashion, so that abilities and capabilities appear and disappear as the game progresses, and represent additional rewards in the training progress. The achievement of a rule or ability constitutes a reward on its own, and in addition further facilitates progress and speed in the game, providing satisfaction and a sense of

accomplishment, as well as a sense of power and ability on the part of the trainee. For example, in a maze type game, the following types of abilities may be introduced and modulated by the systems and methods of this invention:

The ability to make an advantageous decision upon hitting a "wall".

The ability to see goals that lie in the existing path, and to stay on that path.

The ability to "see" adjacent goals, and to change course to pursue them.

The ability to "see" nearby goals, and to change course to pursue them.

The ability to "know" where distant goals lie, and to change course to pursue them.

The ability to "know" where and when special goals exist, and to pursue them.

The ability to "know" where obstructions lie, and to avoid them.

The ability to "know" where "enemies" lie, and to avoid them.

The ability to predict the course of "enemies" and to avoid such routes.

The ability to defend oneself against "enemies" by becoming immune to their effects.

The ability to restrict the movement of "enemies", thus avoiding their effects.

The ability to change course without having to hit a wall.

The ability to change course in the absence of immediately "visible" rewards.

The ability to change course based upon planning of the eventual route.

The ability to change course to avoid unnecessary long routes.

The ability to change course to acquire nearby rewards first, to avoid roundabout routes.

The ability to adjust the speed with which the agent runs the maze.

The ability to travel at a faster speed.

The ability to go faster when there are no goals being acquired, in order to seek distant goals more quickly.

The ability to use random choice, to provide variability in running the maze.

These constitute examples of intelligence and abilities which can be incorporated into a maze type game in accordance with the principles and concepts of the invention.

[0011] In the case of a basket shooting game as an alternate embodiment of a system and method of the invention, the following intelligence and abilities may, for example, be modulated:

The ability of the player to know where the target lies.

The ability of the player to know the movement of the target.

The ability of the player to move in pursuit of a moving target.

The ability of the player to move more quickly in pursuit of a moving target.

The ability of the player to shoot the ball at an opportune time.

The accuracy with which the player shoots the ball.

The ability of the player to anticipate the position of a moving target, and to shoot the ball appropriately.

The ability of the player to acquire additional balls to shoot at the target.

The ability of the player to recover quickly from one shot, in order to make the next.

[0012] The systems and methods of the invention can be applied to any game that includes goal-seeking behavior, and that can be instrumented appropriately to play automatically, and incorporate rules. Such games may include any displays that include "targets" in the general sense, and the ability to keep a score, or demonstrate progress by an appropriate means or method or symbology (collecting rewards, increasing the size or visibility of a display, presenting special displays, giving "levels" of performance, and so on). In this invention, "target" is not limited to a specific object that must be contacted or hit, but can include any goal that can be identified and seen in the progress of viewing the display, listening to the sounds, or feeling vibrotactile stimulation.

[0013] As a result of this method, it is possible to construct gamelike biofeedback systems and displays that have one or more of the following representative properties:

Provide a wide range of feedback performance, rather than a simply scaled variable.

Provide qualitatively different feedback, depending on the trainee's progress.

Provide intuitive visual indicators of the trainee's progress.

Provide feedback in which the level of perceived intelligence in the game reflects the quality of the trainee's performance.

Provide feedback in which the game "player" provides an analog of the trainee.

Provide feedback in which the game "player's" evident intelligence and performance.

Provide a representative of the internal state of the trainee.

Provide feedback in the form of intelligence and empowerment, which reward the trainee.

Provide the reward of seeing the game played differently, or better, as training progresses.

Provide an element of novelty, as the rules and decision-making of the embedded agent change.

Provide a fast visual assessment of the trainee's progress by watching the game progress.

Provide a fast visual assessment of the trainee's state by viewing the current display.

Incorporate assessment directly into the training system or method.

BRIEF DESCRIPTION OF THE FIGURES

[0014] FIG. 1 is a block diagram of the hardware and logical components of the system of the present invention;

[0015] FIG. 2 is a block diagram of the Decision Rule Management software components of an embodiment of the system of the present invention, and

[0016] FIG. 3 is a block diagram of the logical components of an embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED AND ALTERNATE EMBODIMENTS

[0017] The systems and methods of the invention can be embodied in a form that includes a biofeedback monitoring system, a suitable automated processor or computer, and a display that is capable of presenting material of a graphical, auditory, or vibrotactile nature. The system is basically comprised of an overall Decision Rule Application System. This includes the Biofeedback Monitoring System that monitors the Trainee's physiological data. The Biofeedback Monitoring System is interfaced to the Biofeedback Soft-

ware Processor element via a communication channel. The Biofeedback Software Processor is responsible for the control of the system based upon the Trainee's physiological state.

[0018] With reference to FIG. 1, there is illustrated the basic components necessary for a biofeedback session utilizing the system and method of the present invention. The Trainee 1 is connected to the Biofeedback Monitoring System 3 via a link 2 that conveys physiological information to the system. The Biofeedback Monitoring System converts the data via analog to digital conversion, and subsequently conveys digitized physiological data 4 to the Biofeedback Software Processor 5. The Biofeedback Software Processor 5 processes physiological data using algorithms including digital filtering, fast fourier transform, and other mathematical and logical operations. These operations are designed to reflect the current physiological state of the trainee, in particular indicating changes in physiological qualities including but not limited to relaxation, concentration, attention, level of arousal, etc. The derived information 6 is sent to the Decision Rule Management System 8, which manages a set of Decision Rules 10. These rules are conveyed via connection 11, to the Intelligent Biofeedback Display Generator 12. The Intelligent Biofeedback Display Generator 12 receives both the Decision Rule data 11 as well as output 7 from the Biofeedback Software Processor 5. This information includes momentary data about physiological state of the trainee. Based upon the Decision Rule data 11 and the Biofeedback Software Processor data 7, the Intelligent Biofeedback Display Generator 12 controls, via communication channel 13, the Biofeedback Display 14. The Biofeedback Display 14 is responsible for generating the detailed visual, auditory, and vibrotactile feedback information, which is presented to the Trainee in the form of sensory information 15. The Biofeedback Software Processor 5 may manage one or more Decision Rule Management Systems 8, which maintain Decision Rule Sets 10 for use in generating feedback.

[0019] With reference to FIG. 2, there is illustrated the basic components necessary for the Decision Rule Management System. The Condition Analyzer 17 receives information 16 which has been derived from the previously described Biofeedback Software Processor 5. Based on the current set of physiological conditions 18, the Rule Dispatcher 19 determines whether or not a change in rule status is required. If this is the case, the Rule Dispatcher performs the function of modifying the current set of decision rules. Control is then passed, as appropriate, to either the Decision Rule Adder 20, the Decision Rule Deleter 21, or the Decision Rule Modifier 22. The Decision Rule Adder 20, the Decision Rule Deleter 21, and the Decision Rule Modifier 22 have the function of adding, deleting, or modifying the Decision Rules 10, according to prescribed logical and mathematical operations.

[0020] Because Decision Rules 10 can be quantitative in nature, it is possible to modify a quantity associated with a decision rule, in addition to simply adding or deleting a rule. This provides the ability to modulate behavior in a manner that provides a perceived smooth, quantitative set of characteristics, in other words, a sense of "how much." This makes it possible to design contextual displays that appear to have more or less of a quality such as intelligence, rapidity, accuracy, consistency, steadiness, etc.

[0021] Included in the user-perceived qualities that can be included in a system of this type are, in addition to perceived intelligence, qualities including but not limited to: speed, attention, focus, relaxation, distractability, irritability, consistency, reliability, accuracy, and persistence. A Biofeedback Display that incorporates an element such as a simulated human player, a goal-seeking creature, or other content, this element can be imbued with the aforementioned qualities in greater or lesser amounts, under the control of the present invention.

[0022] With reference to FIG. 3, there is illustrated the basic decision elements of an embodiment of the present invention. In this example, three physiological parameters are tested by decisions based on whether or not they exceed defined thresholds. Based on the state of these parameters, four parameters are changed, by virtue of the Decision Rules shown. If all conditions are met, then the speed of the game is increased. Otherwise, it is decreased. In this example, there is a component referred to as the "Enhance Component." If this component is above threshold, then the ability to "Autosteer" is increased. Otherwise, it is decreased. There is a component referred to as the "Low Inhibit." If this component is above threshold, then the jitter present in the game is increased. Otherwise, it is increased. There is a component referred to as the "High Inhibit." If this component is above threshold, the bias present in the game is increased. Otherwise, it is decreased. In this manner, the four characteristics in the game being speed, autosteering ability, jitter, and bias, are changed continually, in response to the trainee's current physiological state. Thus, the player in the game will exhibit various levels of performance, revealed in the form of the speed, steering ability, jitter, and bias in the progress. If this were a skiing game, for example, the skier would change the ability to ski down a hill, with varying amounts of ability. Similarly, in a maze seeking game, the automated player would exhibit varying ability to run the maze, based upon the current levels of the control variables.

[0023] The present invention can be applied to any game or display that can be instrumented appropriately to play automatically, and to incorporate decision rules as a means to modulate the performance of the displayed material. Such games may include any displays that include "targets" in the general sense, and the ability to present goal-seeking behavior, as a means of providing information to a trainee.

1. A system for creating and providing automated visual, auditory, or vibrotactile information for the purposes of biofeedback training via classical and/or operant conditioning, comprising:

sensors for interface with a trainee user of the system that detect biological activity such as EEG brainwaves, skin electrical activity, electrical skin resistance, body temperature, or other physiological variables of the trainee; the system providing a game for the trainee which includes visual, auditory, and/or vibrotactile stimulation or displays, the game further including an element of intelligence selected from the group of: goal-seeking behavior, decision-making, or other discernible actions;

an embedded agent which plays the game in the form of movement, decision-making, and other goal-seeking behavior, that is determined by signals from the sensors.

2. A system for control and change of the perceived level of intelligence, goal-seeking, or decision-making in a game,

which reflects the changes and state of the recorded biological activity of a trainee playing the game,

the system operative to control and change game output variables which are perceived by the trainee such as brightness, contrast, speed, clarity, color, loudness, intensity, or other attributes of an output of the game in response to biofeedback signals received by the system from the trainee.

3. The system of claim 2 operative to enable a game administrator and/or the trainee to observe and measure change or progress in biofeedback training of the trainee by the system by observing and discerning the level of intelligence, goal-seeking, or decision-making evident in the game output.

4. The system of claim 2 operative to enable the trainee to observe a level of intelligence, goal-seeking, or decision-making behavior, and to perceive and train targeted training variables of the game.

5. The system of claim 2 operative to enable the administrator and/or trainee to assess momentary progress of biofeedback training of the trainee by the system by observing a particular decision made by the output system.

6. The system of claim 2 operative to enable any observer of the game to assess momentary progress of the trainee, relative to predetermined training goals, by observing a particular decision made by the output of the system.

7. The system of claim 2 operative to enable the administrator and/or trainee to assess the momentary progress of biofeedback training of the trainee by the system by observing momentary success of intelligence, goal-seeking, or decision-making in connection with the game.

8. The system of claim 2 operative to enable an observer of the game to assess the momentary progress of the trainee, relative to the training goals by observing momentary success of the intelligence, goal-seeking, or decision-making within the game.

9. The system of claim 2 operative to enable an administrator and/or trainee to assess the progress of the training by observing cumulative success of the intelligence, goal-seeking, or decision-making within the game.

10. The system of claim 2 operative to enable an observer to assess a state of the trainee relative to recorded biological activity and training goals of the trainee by observation or recording of cumulative success of intelligence, goal-seeking, or decision-making within the game.

11. The system of claim 2 wherein a level of intelligence in a game is utilized as a biofeedback variable.

12. The system of claim 2 wherein a level of speed evidenced in a game is utilized as a biofeedback variable.

13. The system of claim 2 wherein a level of attention evidenced in a game is utilized as a biofeedback variable.

14. The system of claim 2 wherein a level of focus evident in a game is utilized as a biofeedback variable.

15. The system of claim 2 wherein a level of relaxation evident in a game is utilized as a biofeedback variable.

16. The system of claim 2 wherein a level of distractibility evident in a game is utilized as a biofeedback variable.

17. The system of claim 2 wherein a level of irritability in a game is utilized as a biofeedback variable.

18. The system of claim 2 wherein a level of consistency evident in a game is utilized as a biofeedback variable.

19. The system of claim 2 wherein a level of reliability evident in a game is utilized as a biofeedback variable.

20. The system of claim 2 wherein a level of accuracy evident in a game is utilized as a biofeedback variable.

21. The system of claim 2 wherein a level of performance in a game is utilized as a biofeedback variable.

22. A method of biofeedback training which utilizes a feedback game, wherein actions and events within the feedback game are influenced by biological signals from a trainee observing the feedback game.

23. The method of claim 22 wherein decision-making rules and abilities applicable to an embedded game player are introduced and controlled as types of feedback variables to the trainee.

24. The method of claim 23 wherein abilities of an embedded game player which may be introduced to the trainee and modulated are comprised of the group of:

the ability to make an advantageous decision upon hitting a "wall";

the ability to see goals that lie in the existing path, and to stay on that path;

the ability to "see" adjacent goals, and to change course to pursue them;

the ability to "see" nearby goals, and to change course to pursue them;

the ability to "know" where distant goals lie, and to change course to pursue them;

the ability to "know" where and when special goals exist, and to pursue them;

the ability to "know" where obstructions lie, and to avoid them;

the ability to "know" where "enemies" lie, and to avoid them;

the ability to predict the course of "enemies" and to avoid such routes;

the ability to defend oneself against "enemies" by becoming immune to their effects;

the ability to restrict the movement of "enemies", thus avoiding their effects;

the ability to change course without having to hit a wall;

the ability to change course in the absence of immediately "visible" rewards;

the ability to change course based upon planning of the eventual route;

the ability to change course to avoid unnecessary long routes;

the ability to change course to acquire nearby rewards first, to avoid roundabout routes;

the ability to adjust the speed with which the agent runs the maze;

the ability to travel at a faster speed;

the ability to go faster when there are no goals being acquired, in order to seek distant goals more quickly;

the ability to use random choice, to provide variability in running the maze;

the ability of the player to know where the target lies;

the ability of the player to know the movement of the target;

the ability of the player to move in pursuit of a moving target;

the ability of the player to move more quickly in pursuit of a moving target;

the ability of the player to shoot the ball at an opportune time;

the accuracy with which the player shoots the ball;

the ability of the player to anticipate the position of a moving target, and to shoot the ball appropriately;
the ability of the player to acquire additional balls to shoot at the target, and
the ability of the player to recover quickly from one shot, in order to make the next.

25. The method of claim **22** wherein the feedback game produces a plurality of possible displays selected from the group comprising:

- a display of a wide range of feedback performance, rather than a simply scaled variable;
- a display of qualitatively different feedback, depending on the trainee's progress;
- a display of intuitive visual indicators of the trainee's progress;
- a display of feedback in which the level of perceived intelligence in the game reflects a quality of the trainee's performance;
- a display of feedback in which the game "player" provides an analog of the trainee;

- a display of feedback in which the game "player's" evident intelligence and performance;
- a display of feedback representative of a status of the trainee;
- a display of feedback in the form of intelligence and empowerment reward to the trainee;
- a display of feedback to provide the reward of seeing the game played differently, or better, as training progresses;
- a display to provide an element of novelty, as the rules and decision-making of the embedded agent change;
- a display to provide a fast visual assessment of the trainee's progress by watching the game progress;
- a display to provide a fast visual assessment of the trainee's state by viewing the current display, and
- a display which includes an assessment related to the training method.

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