Quantifying Anticipatory Characteristics

1. The broader agenda

Addressing the various limitations and costs that aging entails has become a major challenge. Many resources are utilized for fighting the limitations of aging as they progressively occur, but few for attenuating the consequences of aging before they become a medical problem.

Seneludens (from the Latin senescere, to "grow old," and ludus, "play") is a broad research project (5-8 years forecasted) that takes a proactive approach to the above-defined subject. It seeks methods for combining the will of the aging to enjoy quality of life without the need for medicine in order to maintain characteristics that make life worth living. *Seneludens* focuses on maintaining anticipatory characteristics during the aging process. Senescence is the stage at which anticipation degrades to such an extent that the body is practically reduced to its physical-chemical reality. Based on the findings of physicians, gerontologists, experts in brain research, cognitive science, and the social sciences, this project attempts to encourage an active lifestyle. In particular, *Seneludens* will stimulate the individual's predisposition to play. A broad variety of games will be designed, based on the specific findings of professionals who study aging. Together with virtual environments designed to appropriately address physical capabilities, such games will entice the aging to remain fit and mentally active, to connect with others, and to remain competitive. Game-supported maintenance of skills and learning will contribute to keeping the elderly independent and capable of further contribution to society. A necessary condition for achieving this long-term goal is the capture and expression of anticipatory characteristics in forms that can be used for modeling new kinds of interaction. Based upon such interactions new applications can be implemented. The proposal herewith submitted is focused on quantifying anticipatory characteristics. We provide the broader agenda, in a rather short-hand formulation, in order to put the proposal submitted in its proper context. No implicit assumptions of automatic support for *Seneludens* in its entirety are made.

2. Anticipation and its condition. An agenda for original research

More than 500 years ago, Leonardo da Vinci (1498) maintained: "…when a man stands motionless upon his feet, if he then extends his arm in front of his chest, he must move backwards a natural weight equal to that both natural and accidental which he moves towards the front." Biologists and biophysicists addressing the notion of postural adjustment (Gahery, 1987, quotes Belenkii, Gurfinkel, Paltzer, 1967) proved that the compensation noticed—the muscles (from the gluteus to the soleus) tighten—as a person raises his arm slightly <u>preceded</u> the beginning of the arm's movement. The compensation was <u>not</u> triggered as a reflex. In other words, the compensatory muscle tightening occurred in anticipation of the action, and was not directly caused by it.

A similar observation was prompted in respect to a relatively simple experience: We often catch an object falling from above or thrown in our direction <u>before</u> actually seeing it (perception), or at least before we can acknowledge having noticed it. In reporting on their investigation of the "proactive nature of the motor system," scientists (Ishida & Sawada, 2004) conclude that the hand's motion preceded the target motion.

In the same vein, the study of motor control system (Wolpert, Ghahramani, 2000) through computational principles of movement—as a new expression of knowledge in neuroscience—led to a model of control, estimation, prediction, and learning in humans based on the assumption of anticipation as a characteristic of the human being. This deductive evidence of anticipation is based on the understanding of perception, control mechanisms, estimation (of distance and interval), prediction, and learning as complex computations.

The baroreflex (Kirchheim, 1976; Abboud and Thames, 1983) adjusts the heart rate in <u>advance</u> in such a way as to maintain blood pressure within safe limits. It is due to anticipation that, when we change position during the daily routine of life (for instance, when we get up from a horizontal position to the verticality expected for moving around), we do not experience the dizziness associated with change in blood pressure (Weigand, 1994). Various other aspects of anticipation pertaining to vision (Berry, et al, 1994; Silvanto et al, 2005), hearing (Aniruddh et al, 2001), and taste (cf. Blaikie, 2000) are on the record of scientific inquiry. They also serve as powerful explanatory models of human performance in sports, military, artistic or scientific endeavors, and in using tools (Nadin, 1999).

In defining an anticipatory system as a complex dynamic entity whose current state depends not just on previous states, but also upon possible future states, we advance a model that reflects the human being's dynamic nature. One notion needs to be spelled out in these preliminary remarks: The living is always a physical entity (Elsasser, 1987, 1998), but one that is capable of anticipation (Rosen, 1985, 1991; Nadin, 1988). The PI of this research project was, concomitant with Rosen, among the first to advance a scientific foundation for the study of anticipatory characteristics (Nadin, 1988). Both Rosen and Nadin noticed that the dynamics of the living is characterized by a progressive increase in anticipation corresponding to experience, in particular learning, but also by a rather steep decline of anticipatory characteristics once the aging process begins (Nadin, 1991).

Indeed, with aging, the compensation expected when a person raises his/her arms diminishes, and at senescence the individual loses balance, often by simply moving an arm. A ball thrown unexpectedly to an elder person prompts a reaction of avoidance rather than the pro-active preparedness leading to a safe catch. The assumption of anticipation evinced by the computational principles of movement mentioned above returns the individual to a physical state in which there is no pro-active component at work. Everything is reduced to a short chain of action-reaction (Kramer et al, 2004). With aging, the anticipatory baroreflex decreases (Bowman et al, 1997); older people become dizzy when getting up (even from a chair), and when atmospheric pressure changes (Aikman, 1997). This very often leads to a predisposition to stay in bed or to sit for longer periods of time, to avoid moving around (activity is in such cases erroneously associated with dizziness). The parallel pursued so far—optimal functioning due to anticipatory characteristics vs. decreasing anticipation during the aging process—is more indicative of a trend than quantified

It is the aim of this project to obtain data regarding the decline in anticipatory characteristics noticeable in aging persons with the aim of quantifying anticipation aspects in general. For this purpose, researchers from brain science, cognitive science, biophysics, gerontology, and computer science will collaborate in gathering such data from human subjects (in that phase of life referred to as "aging"--a rather fuzzy descriptor) as a preliminary to conceiving games and the associated learning. In other words:

a. Define an agenda of research grounded in the many aspects of anticipation as they affect human and social dynamics even beyond the critical aspects of an aging society.
b. Research what it takes to maintain such characteristics over a longer period of time, in particular how to engage the aging in an active way of living (cf. Cassel, 2002) especially through the reward-based model of games (Ball et al, 2002).

Observation: This second aspect is directly related to the management of change and the risks and uncertainty society faces as almost a quarter of the population is affected by the decrease in anticipatory characteristics. The decrease in anticipation takes place during a period of life when this necessarily means to rely more and more on others (AARP, 1997), in particular social institutions requested to adapt swiftly to a new equation of longevity.

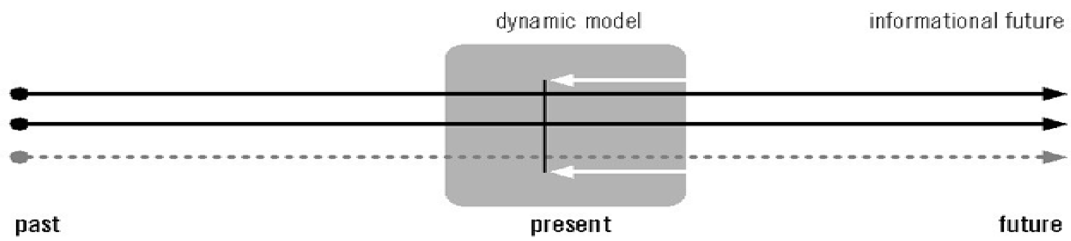
In a number of meetings with health practitioners, brain scientists, biophysicists, neurologists, and gerontologists, the objectives identified above were concretized. The expectation—moreover, the necessity—of quantifying anticipatory characteristics was made very clear. If we want to address the maintenance of anticipation, we not only need to have access to the data that provides evidence of anticipation, but also to define methods and to conceive of means for quantifying those observations.
The website www.anticipation.info, initiated and maintained by the Institute for Research in Anticipatory Systems, serves as a knowledge repository. It makes available hundreds of peer-reviewed articles from leading scientific publications—e.g., Nature, Science, Nature Neuroscience, Gerontology— to researchers in anticipation, as well as to the public at large. It also informs on current development in anticipation research. This repository of knowledge needs to be complemented by a repository of data associated with the theoretical models advanced so far. Quantification of data obtained from scientific observation of anticipation is the first and unavoidable step towards a longer range research dedicated to developing interactive devices that will extend the contribution of anticipatory functions to the life of the aging.

Assuming that it is indeed possible to extend the time period during which anticipation is at work, it will then be necessary to express this possibility in forms that are easy to understand and reproducible. To quantify anticipation means to express it in numbers or matrices; it also means to capture it in other forms, such as visual representations associated with movement (animation), or other actions. Visual forms of expression or multimedia expression (involving time sequences that reflect the dynamics of life) are therefore valid options and we will make use of them. Once we know how to quantify anticipatory functions, we will be in the position to customize the means affording improvement—collectively and individually—and measure the impact of those means.

Given the nature of anticipation, and the variety of perspectives from which it can be approached (e.g., biology, mathematics, physics, philosophy), an interdisciplinary/multi-disciplinary approach must support the project's research agenda. The epistemological foundation for the understanding of anticipatory processes will eventually explain the way the team came together.

2. 1 The subject of quantification: What do we need to measure?

In order to predate a certain outcome—balance, hand motion ahead of target motion, adjustment of heartbeat before changing body position, etc.—anticipatory mechanisms unfold virtually in faster than real time.



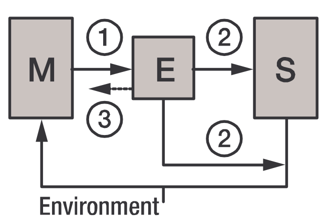
This diagrammatic representation suggests that the future to which the definition refers is a possible future, reached ahead of the action in which the individual is involved. Strictly speaking, this corresponds to a faster "clock." In the human body, various synchronizing mechanisms function at a variety of speeds/rhythms (from extremely fast to very slow). It is possible that this difference in rhythm explains the variety of ways in which anticipatory action, together with learning, takes place. People laugh at jokes before the punchline; they understand a sentence before having entirely heard or read it. They "know" how to fall without harming themselves. To repeat: this anticipation decreases with age. The individual returns to a physical state dominated by action-reaction, and is no longer functioning in a proactive mode.

The diagram suggests that time will have to be measured. The temporal domain to be considered is in the span of milliseconds. What speaks in favor of this expected timeframe is also the brain readiness potential, as expressed in the classical experiments conducted by Libet (1985, 1989).

But time, such as in "How long before the person raises his arms do the muscle in the leg tighten?" is not the only value associated with anticipation that will be quantified.The intensity of the anticipatory action, e.g., how tight the muscle contraction in the leg prior to lifting the arm; the constancy of the anticipation; the influence of the environment, among other values, will need to be quantified as well. The time vector is necessary but not sufficient for the task of defining the various quantifiable aspects of anticipation. We also need a procedural definition, i.e., an understanding of the variety of ways through which anticipation is performed. Such a definition, if we decide to use it, can serve as a possible computer implementation in modeling anticipatory processes (e. g., what guides the falling of a person in terms of cues related to the process?).

A procedural definition can serve as a possible implementation. Informational future means that it pertains to the dynamics of information processes. For instance, to think about a house, and to express this in a drawing is not the same as building it. The information in the drawing might not be sufficient for actually building the house, or it might be incomplete (which is almost always the case). But it guides the action of building, including the determination that some information is missing.

The living system endowed with anticipation contains a model of itself that unfolds in faster than real time (cf. Rosen, 1985; Nadin, 1999; Dubois, 1999). It is an informational future.



In this diagram, the system (S) and the model (M) are connected through effectors. Environment means the whole context. That some of the effector's action on the system endowed with anticipation is modulated by the environment/context is suggested as a way to acknowledge how anticipation and context are related.

A hammer in a person's hand triggers a readiness to hammer: The arm and hand adapt to the weight; hammering is neither too weak for the task nor too excessive. This is an experience everyone shares, taking for granted the anticipation implicit in the action. Due to inexperience (i.e., lack of learning), children do not have the same preparedness and often get hurt as they learn the skill. With aging, the skill diminishes; and, not surprisingly, some older persons see the hammer fly out of their hand. One consequence is that they eventually give up attempting the task. Diminished anticipation acts as an inhibitor. This also applies to physical exercise, the use of tools, and the use of household appliances: reluctant use of faucets, heating appliances, remote controls, and even the telephone (Muller et al, 2002).

Given the informational nature of anticipation, it is not in the realm of medicine (new drugs, for instance) where progress can be made, but rather in the action aspect of human existence. This is where anticipation is expressed and where we want to quantify it and/or describe it qualitatively. We want to understand how anticipation relates to successful actions that maintain the integrity of existence.

Huizinga (1938), and later Callois (1958) dedicated their inquiry to play as an essential element of human social and cultural development. Whether as competitive, driven by chance, involving simulation, or resulting in loss of self-control, playing contributes to problem-solving skills, to intellectual and physical acuity, and to personal expression. Through games, children acquire anticipatory skills. Lack of play in aging adults may result (McEwen and Schmeck, 1995) in the decrease of their anticipatory capabilities. Early research into video games and the elderly (Whitcomb, 1990) resulted in an increase in their cognitive abilities as they played the games they were able to.

In this sense, it is important to emphasize that studies of anticipatory systems (cf. Gentilucci et al, 1988; Gallese, 2000; Rizzolatti et al, 2000) make clear that we can no longer draw a sharp line between acting and perceiving. The research proposed herein builds upon the experimental evidence of the fact that the motor systems controls actions, and that neuronal configurations are to the goal of the action. As Gallese discovered, looking at objects means to "simulate" a potential action using them. In other words, the object representation is transiently integrated in the action simulation. Perceptual processes are part of action. This principle will guide the design of our experiments in quantification.

Multiple frames of reference are at work as anticipation takes place. The coherence of interacting levels of representation results from action. Therefore, we conceived of a generic notion of action associated with play and embodied in games through which aging individuals can be engaged. But before conceiving particular games—which will not happen during this phase of the global project—we need to understand how anticipatory characteristics, as part of the individual's cognitive make-up are associated with the motor system. We need to understand how reward mechanisms prompt processes leading to the maintenance, if not improvement of anticipation. Therefore, the focus of this research on quantifying anticipation will also refer to the role of the context.

3. The Research Team – The Challenge of Advanced Knowledge Integration

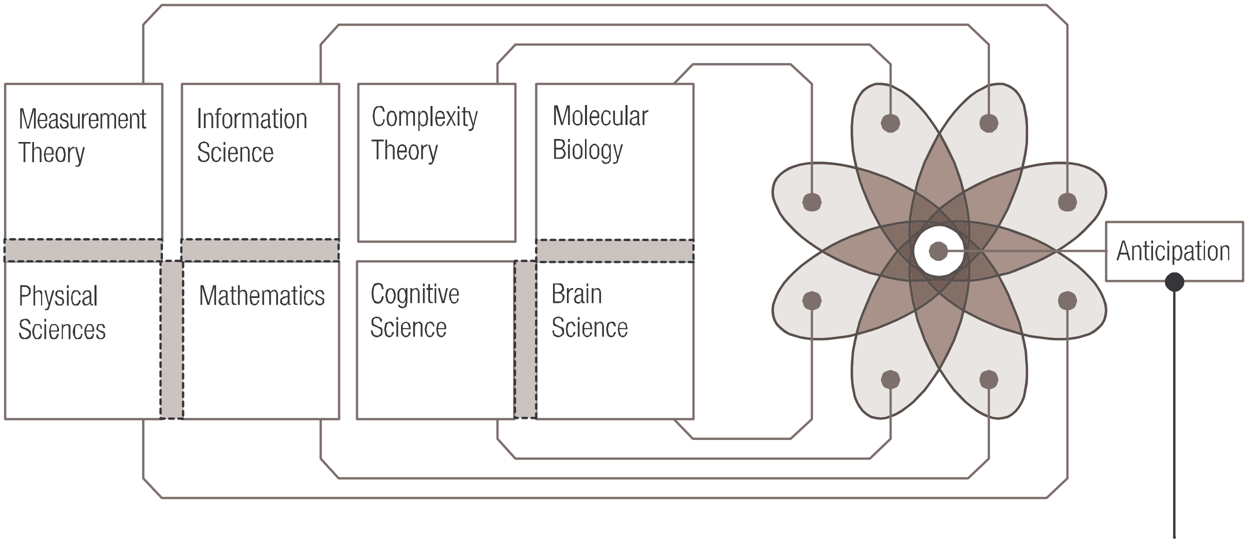
Understanding the dynamics of human action and development means to understand the new relationship between human beings and changes in society. The scale of humankind has reached a threshold. Within this scale, the fast increase in the number of persons enjoying a longer life (cf. Greenspan, 2003) is reflected in new requirements for human activities and for allocation of means to meet the challenge. What should be done and how is by no means obvious. As the complexity of the challenges presented by interactions across generational borders increases, we are faced with the need to come up with effective ways to gain knowledge about the process and to eventually turn this knowledge into effective practical solutions. In the case of this project, interdisciplinarity and multidisciplinarity are not the reflection of meeting a formal expectation, but a necessary condition. The partnerships developed in formulating the broader goal of the project reflects the fact that the dynamics of aging and the desire to generate viable ways to affect the process through effective means can be approached only through a convergent effort involving science, technology, art, and social sciences. Some ongoing activities reflect dedication to the investigation agenda expressed in the project: the conference, "Reprogramming the Human Brain (University of Texas-Dallas, April 10-11, 2005); the visit and lecture, sponsored by the Jonsson School of Engineering and Computer Science and the by the Institute for the Research in Anticipatory Systems by Professor L.A. Zadeh (member of the Scientific Advisory Board of the Institute). This lecture will be focused on perception based computation and its relevance to our project. The common underlying principles, worked out in recent months by the research team, are themselves at a convergence point: aging, plasticity, anticipation, engagement through activity, learning. Students, both at undergraduate and graduate level are actively involved in the preparation phase. The two suggestions for a possible improved motion capture model (see below **Measurable Improvements in Human Performance Assessment**) originated from them. The integrating vocabulary which the groups involved developed and will continue to develop is probably the interface that should allow us to maintain disciplinary depth while striving towards interdisciplinary breadth.

Anticipation is the focus. As such, it is made evident at the intersection of a variety of disciplines: physics, complexity theory, information sciences, mathematics, biology, brain science, cognitive science, and others. The intersection of such disciplines (cf. diagram below) suggests challenges in the form of disciplinary competence: the re-wiring of the human brain in aging individuals engaged in meaningful actions; the computational description of possibility-driven information processes. Interdisciplinary integration of results has a clear purpose: once quantification of anticipatory characteristics is achieved, it has to serve as common foundation for customized forms of individual engagement particularly pertinent to the aging.

The difficulty in developing teams to produce knowledge of interdisciplinary nature is not as such organizational as it is conceptual. The Center for Brain Health of the University of Texas-Dallas is located in the vicinity of UT-Southwestern, which has an exceptional imaging facility that the Center uses. Other members of the research team are at various locations in Dallas and Richardson, but also in Boulder, Colorado, Bloomington, Indiana, and Bonn Germany. What is essential is the common understanding of the conceptual goal. Therefore, the expressive unifying language should not alter the precise language of specialized investigation. And as those involved in the project well know, it should not affect our ability to communicate with those who are the focus of the effort: aging individuals who have less in common than what is the subject of our investigation. More precisely, various ethnic and racial backgrounds, various family experiences, various work experiences, various economic backgrounds, etc., will have to be carefully accounted for.

With the help of a diagram we would like to clarify the nature of the working relation of the researchers involved: The Center for Brain Health and a Senior Researcher, qualified in cognitive science, working for the Institute for the Research in Anticipatory Systems will be focused on brain imaging and associated techniques. Quantifying attempts in the Motion Capture Lab, and the appropriate data processing in the antE Lab, will be coordinated through the Institute with the participation of 2 Co-PI's, from the Computer Science Department and from the Interactive Arts and Engineering area. Coordination between the two teams should help us define similar samples, and to cross-reference the data. Mathematical modeling and associated data compatibility measures will be provided through the The Interdisciplinary Center for Complex Systems (**IZKS**) at the University of Bonn. Once data is sampled the project will benefit from the expertise in data fitting acquired through the AI lab at UT Dallas. During the entire project, participants will have access to the knowledge and expertise acquired at the Center for LifeLong Learning and Design at the University of Colorado, Boulder, which will serve as a Consultant. Finally, once data is generated and a course of action for designing games becomes possible, a Co-PI with expertise in game conception and implementation will conduct workshops with aim of having future beneficiaries define the types of activities in which they prefer to be engaged. The learning aspect will play a major role in this respect, reason for which the consultant will advise the workshop initiator.

Based on the considerations spelled out above, we derived the following assignment mapping and integration representation for the research:



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With this conceptual map clarified, we can now detail the various forms through which quantification will be performed. The convergence of cognitive and social science knowledge with computer-based implementations (from the customization procedure to the new form of interactivity) will be pursued from the research agenda to the educational level. We have some interesting developments in this direction which will be presented as we detail the aspects of quantification.

Since many activities will take place in parallel, the following sequential narration (identifying years in the project) should not be construed as a plan for action, but rather as descriptive of the various contributions expected from the participants in the project in a sequential manner.

3.1 First Year

Cognitive characteristics and functional brain imaging
Specific Aims:

I. To compare behavioral responses in college age students (n=50), cognitively normal Young Old (60-79 years) (n =50) and cognitively normal Old Old (>80 years) (n=50) on multiple measures that could involve anticipation.

II. To investigate brain activation patterns during preparatory processing and actual task performance using function brain imaging (fMRI) across the same 3 age groups with 20 subjects in each group.

III. To document changes in behavioral performance after training on tasks that include anticipatory strategies

Hypotheses:
These are based on the research results shared in the community of scientists dedicated to the area of anticipation (cf. Critchley et al, 2001)

1) Older adults show diminished performance on tasks such as the ability to anticipate which decision/choice will lead to higher returns.
2) Compared to younger adults, older adults show altered activity in brain regions associated with anticipatory characteristics.
3) Behavioral training will improve performance on the anticipation tasks.

Purpose

We propose to apply the theoretical framework of Anticipatory Systems as developed by the PI in order to elucidate decline in cognition and alterations in brain function with normal aging. Furthermore, we propose that this novel approach will allow us to test specific hypotheses as to whether a course of action, such as playing in a game structured manner, can be developed to enhance anticipatory behavior and the corresponding brain function in older adults. This research will incorporate cognitive tasks to measure different aspects of anticipation and functional brain imaging to view brain activation patterns during preparatory processing.

Selected dimensions of anticipation as set forth by Nadin (2003) to be quantified including:

1. Anticipation of salient events in the present that is determined by a future state.
   Cognitive Measure: a prospective memory task where one has to respond in the present to remember to do some future event.

2. Anticipation of reward or punishment that serves to guide a course of action

   A stimulus cue that predicts a reward invokes a state of anticipation in the subject. Animal studies have shown that this anticipatory delay after cue onset is reflected in the sustained neural firing that persists for a few seconds before the reward is delivered (Schultz et. al., 1992).

   Cognitive Measure:
   - A gambling task involving choices that bring large winnings, small winnings or large losses. The subject must respond quickly if the cue signals a small reward (active avoidance).
   - A selective learning task tapping ability to adopt a strategy to encode and retrieve high value information over words with negative value.

3. Anticipation as an expression of the connectedness of the world
   Cognitive Measure: Task requiring that one predict the intentions behind another speaker's indirect speech acts

4. Anticipation as a mechanism of synchronization and integration
   <u>*Cognitive measure:*</u> Task of recognition of shared meaning of novel proverbs based on similar integrated meaning.

The second goal will be to investigate brain activation patterns during preparatory processing and actual task performance using function brain imaging (fMRI) across the same 3 age groups.

In humans, fMRI studies have shown that the ventral striatum is activated in anticipation of monetary rewards (Berns et al., 2001; O'Doherty et al., 2002). In addition to the processing of reward stimuli, the striatal reward circuitry is also activated in response to aversive or intense stimuli (Sorg and Kalivas, 1991; Becerra et al., 2001). However, these regions are not activated in anticipation when the aversive stimulus is mild (taste of saline) (O'Doherty et al. 2002). A recent study demonstrated that anticipation of a moderate aversive stimulus does activate the ventral striatum (Jensen et. al., 2003).

The participants will be imaged using fMRI during the time between instruction and the presentation of the cognitive task. We will also study how extinction of a rewarding or aversive stimulus modultes brain responses during anticipation. We predict that frontoparietal networks, which have been associated with anticipatory processing, will show decreased activation in older participants as compared to younger adults during the preparatory processing stage.

Based on this evidence, we propose to design behavioral tasks that emphasize training of anticipation strategies. We will randomize 30 participants that fall one standard deviation below the mean on 3 anticipation tasks into a treatment group and a control social interaction group.

3. 2 Year 2

Motion capture

Given the fact that using motion capture for quantifying anticipatory characteristics is a novel path, and that motion capture is little known in its methodological aspect, we have to give a short description of the procedure. Each detail is relevant to the intended activity, and can be seen as part of the contribution (cf. intellectual merit and broader impact) the research will bring to the broader subject **(**Human and Social Dynamics)

3. 2. 1 3D Motion Capture System

As shown in Figure 1, the motion capture lab in The University of Texas at Dallas is equipped with 16 Vicon cameras and the Vicon iQ Workstation software. Here, a performer (or subject) wears a suit of non-reflective material and about 44 markers are attached all over the body covering each joint. The captured motion of the subject is processed by a data station (to which the 16 cameras are connected).

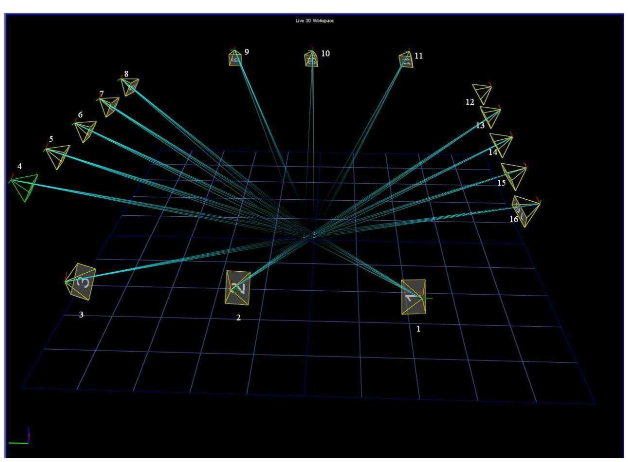

Figure 1: 3D Motion Cameras

The processed data at the data station can be exported into a format called *Comma Separated Value (CSV)*. CSV format file is in the form of matrix. One matrix represents the single motion performed by the subject and different matrices would represent different motions. The data from all these cameras are acquired in the form of frames at a speed of about 90 – 120 fps, the speed varying with the traffic of data from each camera. Each row in matrix represents corresponding frame i.e. row 1 gives the details of data captured in frame 1; row 2 corresponds to frame 2 and so on. For a single human motion of, let us say 10 seconds, the matrix may consist of 900 – 1200 rows. The exact number of rows is decided by the local speed of the performance of the subject. There are 2 types of CSV formats:

- Global type where the translational and positional data is with respect to fixed global co-ordinate system.
- Local type that follows the hierarchy of the body segments. The hierarchy works as follows: the parent node of the toe segment is foot whose parent segment is tibia. The tibia is again a child segment of the femur segment which ultimately is a child segment of pelvis. In local co-ordinate system we treat pelvis segment/node as a *root node* and we get the local co-ordinates of other segments with regard to pelvis segment or node (i.e., in the local co-ordinate system we keep origin at pelvis segment). The rotation and translation of root segment is always global.

3. 2. 2 Global Representation

The human body consists of 19 segments: head, 2 clavicles, 2 shoulder blades, 2 humerus, 2 hands, thorax, pelvis, 2 femurs, 2 tibias, 2 feet, 2 toes (2 segments: 1 for left & another for right). In quantifying anticipatory characteristics we need to account for all these parts, although in a different way than in kinesthetics (which is focused on the kinematics aspect of the body movement).

In the global type format, we have six columns for each of the 19 body segments: i.e., 114 columns. Out of these 6 columns, 3 columns give global rotational axes information in the form of degree and other 3 columns give the global translation of respective segments in the form of millimeters. The origin of the system is defined at the calibration time using an L-frame (L frame is a triangular wand, and one corner of this L-frame decides the origin of this 3D space i.e. (0, 0, 0)). The global CSV translational data of each body segment can be denoted by the tuple<name of segment - T-X, T-Y, T-Z> in CSV file with respect to this origin and the rotational data describing the orientation of the segment can be denoted by the tuple <name of segment – A-X, A-Y, A-Z>. Hence, in the global type CSV file, there are six columns for each segment in order <segment – A-X, A-Y, A-Z, T-X, T-Y, T-Z>. In Global output format, the translational data gives the 3D co-ordinates of the segment with regards to global co-ordinate system.

Considering the rotational data, it can be exported in two different forms: Euler angles or Angle axis. The three numbers of an Angle Axis output format describe a vector. The direction of the vector is an arbitrary axis rotation and the amplitude of the vector corresponds to the amount of rotation in degrees. Whereas Euler Angles directly give the angle of rotation about X, Y and Z axes and hence we will mainly concentrate on the Euler angles. Euler angles are rotations about each axis in a particular order: A-X, A-Y, A-Z would be a rotation first about the X axis of the joint/segment then a rotation about the Y and lastly, a rotation about the Z. For the Global CSV representation, the rotations will be relative to the global coordinate system.

3. 2. 3 Local Representation

If the output type is Local, then the rotations would be relative to the parent joint. For example, the rotations of the left knee joint would be relative the left hip and the rotation of the left hip would be relative to the pelvis. Since typically the pelvis is the root segment its' rotation and position would be relative to the global coordinates. Interestingly, the translational data comes in to picture only when export output type is global. The reason is that for local representation, the translation for all segments except root/pelvis segment is 0, since they only rotate with respect to the parent joint/segment.

3. 2. 4 An Example

Table 1 shows a partial matrix structure just to represent the captured data form the 3D Motion Capture Cameras. This structure shows the data for pelvis node in first frame. Likewise in this frame we have data for all other 18 segments. And in all other subsequent frames we get data for all segments. As we can see in first frame global position of pelvis segment in 3D space is (590.27, 166.42, 797.57). And it is rotated -4.63 degrees about X-axis, -36.23 about Y-axis and 176.46 about Z-axis. Similarly, data is also shown for second frame. Note that this table describes the data for the pelvis segment and hence is a typical representation for both local and global representations (since the pelvis segment also has translation data for local representation also).

Frame	pelvis<A-X>	pelvis<A-Y>	pelvis<A-Z>	pelvis<T-X>	pelvis<T-Y>	pelvis<T-Z>	…
1	-4.62953	-36.2313	176.458	590.269	166.422	797.569	
2	-4.65407	-36.2417	176.453	590.039	166.612	797.706	
3	▪	▪	▪	▪	▪	▪	
4	▪	▪	▪	▪	▪	▪	
▪	▪	▪	▪	▪	▪	▪	
▪							
▪							

Order of generated matrix = [Number of Frames] x [(Number of subjects) * (6 * Number of Segments)]

Table 1: Example CSV Matrix for Pelvis Segment

3. 2. 5 Multiple Performers

If the motions are performed by two individuals simultaneously the amount of data we are getting from cameras will be doubled, as both persons are suited with equal amount of markers and performing motions in front of cameras. Each subject will have its own local readings and also global readings for all the markers on these two individuals with regard to global co-ordinate system. So in general, the order of the CSV matrix generated is given in Table 1.

3. 2. 6 Anticipation and Captured 3D Data

The data station processes data from each camera taking into account the values for every reflective marker on the subject's body and ultimately gives the most efficient and highly processed data in the form of rotational and positional data of segments. Now, if we consider left femur segment, its translational and rotational information is calculated by processing the translational and rotational information of the left-back waist marker, left-front waist marker, right-back waist marker, right-front waist marker and thigh marker (in short, the surrounding markers). For instance, when a subject only rotates his right thigh then only right femur, right tibia, right foot and right toe will be affected, because when an individual rotates his right hind limb only markers attached to it will be rotating or translating. Other markers will be still. Hence, there will be data change only for those segments that are surrounded by these affected markers. Other segments such as fore limb or head segment will notify no change in data (unless the individual moves while rotating his/her right hind limb).

The above observation will be used to test the anticipatory movements of a human being. For instance, experiments will be conducted to test how the leg portions of the body moves in anticipation to a forward bending motion of the upper body, in order to keep a balance. Such experiments with single human anticipation will be conducted with the captured motion data in the Local CSV format. Another interesting possibility is to test anticipatory gestures when more than one individual is involved. For instance, the captured motion data of two hindividuals in the Global CSV format can be used to analyze how one person anticipates and reacts to another person's movement. The movement captured is natural, there are no physical limitations, we are translating the richness of action into numbers that express the correlation among many factors (physical, cognitive, learning, etc.).

3. 3 Third year

3. 3. 1 Comparative studies based on motion capture

From the perspective of the interactive arts, human performance assessment for a variety of reasons (including training and simulation) is significantly advanced through the use of several emerging technologies: Optical Human Performance Capture (OHPC), first-person gaming strategies and trainee self-evaluation based upon level qualification in simulation games. The University of Texas at Dallas made a major investment in the latest three-dimensional, optical performance capture equipment under the assumption that novel scientific applications will be conceived, tested and implemented. This equipment (described under 3.2.1) permits the acquisition of metric measures for full motion interactions of human subjects. In fact, the interaction of five human subjects can be captured simultaneously and associated with metrics with accuracy. These interactions can be assessed and compared to earlier performance as a measure of improvement over time. The motion tracking can then be assigned to computer-generated characters. These characters can be rendered in real-time animation during a training assessment session. These animated interactions provide the context for the subject (aging person whose anticipatory characteristics we will quantify) to practice and develop successful strategies. The subject's strategies are assigned an evaluative score. The score encourages repeated play and efforts to improve individual performance. Using modified "Off -The-Self" gaming engines, with levels of increasing difficulty, the subject becomes an active participant in self-assessment and comparative performance improvement. This project takes advantage of the new technologies mentioned above to significantly advance motion capture and thus training and assessment reliability. In assessing the characteristics of the aging, we can at the same time consider scenarios of play and game involvement which correspond to the profile of the individual. This is in line with the goal of this particular research.

3.3.1 SIGNIFICANCE

We realized that the perspective of anticipation will allow us to perform better in what became one of our major research goals: improved human performance. In the case of the aging, the accent is not on training, but on finding out what kind of actions are indicated for their maintenance of cognitive and physical abilities. Learning based on playing and games is such an action.

Improved reliability of training for human performance in complex settings has a broad significance. The project demonstrates the integration of the aging's motivation to improve performance in a series of complex, unexpected scenarios. Repeated "play" in a familiar, game-like setting encourages the individual to develop multiple strategies to meet desired goals. We will keep a record of such alternatives as they emerge in the spontaneous behavior of aging persons. They correspond to a "know yourself better" path of self-education. The individual is encouraged develop increased anticipation skills in dynamic (the dynamics corresponds to the age) settings and to develop a facility to choose appropriate strategies based upon the actions and reactions of others. Our contribution to the quantifying of anticipatory characteristics is concretized in the following:

1. design experiments appropriate to the aging and their respective mobility
2. express results in the formats made available by the system as well as in visual form (for instance, high resolution video)
3. make the data available to the participants in the project
4. coordinate with the brain imaging team and offer assistance with data for their experiment design
5. establish and maintain a database of quantified anticipatory aspects pertinent to the aging
6. generate from the database variations with aim of identifying types of shared characteristics
7. interact with the MIME group in order to support the preparation of the workshops
8. continue to refine the data based on feedback from workshops
9. simulate game situations with the aim of testing possible game narratives

3. 3. 2 MEASURABLE IMPROVEMENTS IN HUMAN PERFORMANCE ASSESSMENT

The project has "measurable achievement" at its very core, because we want to associate quantified anticipatory characteristics to improved action, to successful independent living.

The project proposed will bind anticipation quantification and individual assessment. We will consider the individuals and their anticipatory performance as equivalent to what we express in training programs as "game score,"(cf. visual perception training using multimedia, cf. Adelman, 1989). An example will illustrate what we have in mind. It is known (Henriksson, et al 2004) that physically active older adults display alterations in gait initiation. An understanding of age-related changes in motor behavior is important when considering the design of assessment programs for fall-prevention in the elderly that might be associated with playing and games in this project.

3. 3. 2. 1 A task driven approach

3. 3. 2. 1. 1 Gait initiation is a phase of walking during which falls often take place. In our research, we can capture the motion of healthy and younger persons and compare strategies adults have during gait initiation. Literature (cf. above) makes us aware that elderly, but also young subjects, with gait associated problems lacked tibalis anterior (TA) anticipatory onset. However TA anticipation increased with trial number (practice) in the elderly group. When the starting leg was predetermined, the deficiency in TA anticipation was no longer apparent. In the stance leg all forces were smaller and lateral gastrognemius (LG) muscles was recruited later.

3. 3. 2. 1. 2 Games based training for the recruitment of muscles that can help maintain balance will prove very important. We can provide for this the data. Indeed, we will quantify ankle muscle activation in relation to gait initiation. From training experience we know that gait initiation changes significantly when the starting leg was predetermined. In the elderly, this change will be affected with repetition. Our task will be to quantify how this happens. A full inventory of such tasks is not available.

This is an original contribution which over time might help the project expand its focus from quantifying anticipation to building behavioral therapy facilities endowed with quality assessment procedures (how successful is the game therapy?). The project will accomplish this in the context of a highly complex engaging scenario, with ever changing events demanding the individual’s attention. The provision of quantitative information on the aging’s response time, strategy selection (how does an aging person play?), and evaluations on the performance can be tracked and quantified for analysis for an entire program of therapy.

3. 3. 3 Further Quantifying Tasks

The motion capture lab allows for realistic settings. We could imagine situations in which action, defining the core of anticipation, is the focus: catch a ball thrown from behind a wall. We know (cf. Zacks, 2004) that, in an experiment in which the object is moving randomly, a subject tends to anticipate the position of the two spots; in addition, it appears that sometimes humans will, in segmenting the space of possible positions, anticipate a movement that hasn’t happened yet. In throwing a ball to be caught we could quantify how the action triggering the anticipatory response is distributed within a broad range of subjects. The movement itself can be further modeled and the animations generated can be analyzed for movement integrity. Such an experiment, as well as a variety of other relevant situations, can only result from interaction with the team focused on brain imaging and with the Institute for the Research in Anticipatory Systems, which coordinates the interaction among the many scholars involved.

Parallel to the brain imaging, we will quantify aspects of anticipation pertinent to

1. anticipation as a feedback mechanism
2. anticipation and the use of tools, in particular, digitally driven
3. synchronization mechanisms
4. collision avoidance

In each of these cases, experiments will be designed so that the impact on those involved in the motion in the lab is reduced to zero. For instance, instead of a collision with another senior, we will provide a virtual person (as projection); in the case of quantifying anticipation involved in the use of tools (cf. Novak, 2003), we will use the VR glove in order to simulate reduced levels of interaction with the tool, corresponding to the individual performance of the aging person.

4. Student participation

Over the entire duration of the project we will encourage student participation. At this time, we can report on two developments suggested by students and which will be pursued in parallel to the quantifying attempts detailed above.

4. 1 Quantifying motion details by developing an original higher resolution motion capture Environment

To supplement the motion capture system available, students are in the process of designing a wireless, portable module to obtain additional information for a number of points, in particular for affording more detail. To each coordinate in the motion capture scheme, this will add:

Orientation – as measured by electronic compass – within 5 degrees precision.
Relative tilt – as measured by a grav/tilt sensor.
Spin – as measured by Gyro.

In short, the module would qualify points of interest through 6 coordinates, and thus better capture the dynamics of the body movement. Individual sensor modules in the process of being developed will be battery powered.

We are looking for a low cost and simple design solution conducive to achieving a resolution that helps in quantifying anticipation. Initial designs for the remote sensors suggest the following configuration: magnetic sensors for 3D compass, sensors for orientation, gyroscope for angular spin.
One example to use would be hand motion capture. It will involve 16 small sensors. A single reflective sensor plus the larger remote sensor version of the above establishes position and also helps in tracking the movement in detail. sixteen smaller sensors in a light, tight glove might capture the actions of a complete hand. When arms, hands, feet, and facial features are considered, one can see the requirement for large numbers of independent sensors. The new sensor mounts on a finger, toes, or detailed facial features. We can think of this additional facility as a “micro capture” component. Consider capturing the full range of movement as a detailed angle, tilt, and spin database. Such a database could serve researchers extract patterns of anticipatory behavior and associate them with the sensory-motoric system.

This extension of the ability to capture motion in more detail than the facility already in place is a good example of how the focus on quantifying anticipation with the aim of developing games for the aging is meeting educational goals. It is the students who suggested the idea, and we will stimulate them to implement it and become part of the larger project. This extension, from which the project will benefit to a great extent, is conducive to more applications which, in the long run, will justify the investment in materials and programming.

4. 2 Another possible development that resulted from interaction with students as the research project was articulated, is the area known as face description and skin learning. Although these measures do not directly quantify anticipation, they are indicative of anticipation based action.

Applications such as face recognition, gesture analysis (face and hands), and movement tracking make use of such techniques. The system suggested so far by students interacting with the PI provides two streams of information at the same time: coordinates and chroma based data (relating to the variations in color).

Face color variations are described even under difficult light conditions (side lights or bad camera calibration in the motion capture lab, for example). A face is characterized by its movement, color, and outlines. These are not subject to motion capture. But when they are realized at the end of the localization process, the fusion of these criteria makes it possible to use relevant features, one at every moment. To catch a ball or avoid a fast moving object often leads to a facial expression indicative of the anticipation process (on avoiding danger, one sweats without really knowing why until the person realizes the past danger, cf. Hopfinger et al, 2000).

In currently practiced methods still images are subject to detailed analysis. The students in the project suggested the use of temporal information redundancy in the video stream. This makes possible a robust face localization after an initial training of one to two seconds.

As the project unfolds, there is a good possibility that this development, indicative of synergies, will help us better understand the variety of ways through which anticipation is expressed. At this time, we do not yet count on significant data to be obtained, but we would like to keep the momentum in the students' contribution to new methods for quantifying anticipatory characteristics.

5. Workshops

The entire project is guided by the understanding of the role psychological and cognitive factors play in conceiving games for the aging. We will be directed by the quantified anticipatory characteristics, but we will also take into consideration parameters such as:

a. Motivation; **b.** Task difficulty; **c.** Emotion; **d.** Attention; **e.** Working memory; **f.** Spatial awareness; **g.** Speed of processing and reaction time.

While it is too early to detail all these, and other factors, primarily cultural, we will a dialog with the beneficiaries initiate in the final phase of this research. They are not only subject to our quantifying attempts, but a main factor in thinking about how a behavioral therapy might eventually be implemented. Therefore, one of the Co-PI's will focus on an ethnographic study of senior citizens as game designers, as those who conceive the type of games they would be interested in.

5. 1 Objectives:

Parallel to the major quantifying effort, we would like to start the thought process leading to the games meant to help people in the process of aging to maintain their anticipatory characteristics.

5. 1. 1 One of the major avenues considered is the involvement of those for which the broader project was conceived in the first place. Dialog, firmly founded in the scientific foundation we pursue, should allow us to understand what could motivate an aging person, man or women, to dedicate time and energy to playing. i.e. get involved with games from which they will benefit in the long run. Literature is guiding the effort (cf. McClure, 1985, Morlock, et al, 1985, Drew, 1986, Clark, 1987), but we have to be aware of the fact that little research, if any, pursued this subject systematically.

5. 1. 2 Although the Institute for Interactive Arts and Engineering developed a focus on games, the research will integrate a group, from Indiana University, already experienced in the dialog with those for whom games are developed.

5. 2 Rational

Games are designed by game designers for others interested in playing. Usually they themselves are the first "others", and those who are part of the game culture testify to the many idiosyncracies of game development. One of the complaints about computer games is that they are designed by and for young males, so the target audience is young males. In playing, these young males develop anticipatory characteristics which in some cases proved to be an asset for their careers (pilots, as evidence shows, are often trained through game experience). Females rarely get involved with games. Moreover, seniors, even those who adopted the computer, are rarely involved in the game culture. Obviously, seniors are very different from young males. Experience suggests two ways to identify the play needs of seniors.

5. 2. 1 One way is audience analysis: ask seniors how they would like to play. A limitation of this method is that it usually consists of asking and talking about existing games, which limits the discussion to existing characters and narrations designed by and for young males.

5. 2. 2 An alternative to this approach would be to guide interested seniors as game/play designers. This would entice them to design forms of playing, and thus activities, which appeal to them. Essentially, this means to carrying out ethnographic game design studies.

The MIME lab at Indiana University acquired competence in this domain. Their proposal, which is integrated with the quantifying aspects described so far, is to conduct a series of 5 workshops around the country. The goal is to use the data acquired (cf. **3. 1**; **3. 2**, see above) and develop teams of literally senior game designers. They would create game design documents of play, i.e. narrations and associated characters, for games they would like to play. These would be weeklong workshops focused on:

1. What kind of narrations correspond to the dynamics of the aging
2. What kind of rewards (associated with games) should be considered
3. What kind of interactions would have to be supported; which should be avoided
4. What is the attention span the game can consider when addressing aging (cf. Riddick, 1987, Weisman, 1983)
5. Is there a learning curve that optimally maintains interest
6. How much physical and how much cognitive effort is acceptable; better yet, how to integrate cognitive and physical effort associated with the game
7. The best games are co-produced by the players. Can the same hold true for aging individuals?
8. How to work on games in ways that make them interesting both for men and women in the process of aging

The basic information about games would be covered from the history of computer games to technical aspects of computer games involving art, music, storytelling and programming needed to create a computer game. The output from each of these workshops will consist of small exploratory ideas, usually 15 per person and 3 large game design documents created by teams of 3-5 senior designers at each workshop. All the ideas and game design documents will be analyzed and coded to look for common play elements unique to seniors.

The results of this study, that is founded in the anticipation perspective of this research, will serve in the next phase of *Seneludens* for actual game development. This academic research would be not only of interest to game developers, but will allow the project in its broader scope to unfold beyond the quantifying stage to which this research proposal is currently limited.

6. Management plan

1. The specific responsibilities of the Principal Investigator are described in the Proposal. The PI (Mihai Nadin) and the Institute for Research in Anticipatory Systems formulated the theoretic framework for the research and will effectively take part in a) design of experiments; b) implementations; c) database construction; d) interaction among various participants at various times; e) refining criteria; f) conception and implementation of interactive tools (seminar, website, meetings in Washington DC, other meetings); g) international collaboration.

2. Co-PI Chapman will be responsible for the imaging component. She will continue interaction with the other groups and eventually refine measurements/tests as appropriate to interaction. The BrainHealth Center will provide feedback during the entire 3 year research.

3. Co-PIs Prabhakaran and Linehan will be responsible for data acquisition in the Motion Capture Lab; they will seek the interaction with the imaging group and integrate feedback in the design of their experiments.

4. Co-PI Gillespie will be responsible for developing game workshops inspired and guided by the data acquired through brain imaging and motion capture. It is important to engage all possible groups (women and men from various ethnographic, cultural, economic, ethnic, social, political etc. groups).

5. Navzer Engineer, as the post-doctoral researcher assigned to the Institute for Research in Anticipatory Systems participates in all data acquisition phases; acts as interface among all groups; and effectively supports the sampling of subjects and the appropriate selection procedure for all phases; maintains the record of activities as they unfold; and reports on every meeting and on the relation between work done and work pending.

6. Fischer provides consulting, according to the timeline, in the preliminary phase (participation in the start-up seminar); in the intermediary phases following year 1, year 2, and year 3 of data acquisition; and especially in the final phase, in which learning aspects and game implementations become the focus.

7. According to the Letter of Commitment from the IZKS-Bonn, Dr. Albeverio and his team will provide the mathematical expertise in the attempt to map from anticipatory characteristics to cognitive-based game narrations. The German team has access to the data generated and will produce effective mathematical representation that will translate into specifications for interactive applications, in particular for game engine design.

Concrete aspects of management and interaction across institutes and disciplines are spelled out below.

The project will be launched during a 2-day seminar (see Budget items G6 for year 1; E1, 2, years 1, 2, 3), during which all project participants, including consultants and the foreign partner, will attend. The seminar will address the following:

1. What each participant must provide (deliverables)
2. What each participant should receive from the other participants and the consultants
3. Functionality of the Website.

Dedicated Website

To ensure transparency and optimal communication among project participants, a website dedicated to the project (see Budget items A3, G1, years 1, 2, 3) will serve as a repository and provide tools for interaction among participants. The website will also serve as a Preliminary Report publication medium. It should be possible to maintain a website with internal communication functions (i.e., an Intranet), in addition to a clearly defined public access facility.

Overall Coordination

The overall coordinating function for the entire project will be exercised by the antÉ – Institute for Research in Anticipatory Systems, situated on the University of Texas – Dallas campus. A senior researcher/Post Doc (see Budget item B1, years 1, 2) from the Institute, who is also directly involved in the project, will ensure that all partners maintain the necessary communication through the website and the associated Intranet. Progress reports will be posted as each researcher sees fit; a quarterly progress report will be obligatory. All comments to the reports will be shared among all participating researchers.

Meetings

1. Local

Should special situations arise, the PI and Co-PIs will meet, as a whole group or on a one-to-one basis, as deemed fit. A summary of such meetings will be posted on the Intranet. Given that coordination is required between the Center for Brain Health (at UT-Southwestern) and the Motion Capture Lab (UT-Dallas), and given that the design of experiments require the presence of the PI, meetings will take place alternately at each campus. Summaries of the meetings will be posted on the Intranet.

2. At the National Science Foundation (Washington DC area)

Presence at the annual meeting of the National Science Foundation in the Washington DC area is obligatory (see Budget item E1, years 1, 2, 3). Once a year, prior to this meeting the Coordinator will prepare a partial report that reflects accomplishments of the previous year. This report will be distributed via the Intranet; it will also distributed to all interested researchers attending the annual NSF meetings. After each NSF meeting, the PI and attending Co-PI will share items of interest resulting from the visit to NSF with other project participants.

3. Special Meetings

a) A special coordination effort is focused on mapping from the quantified anticipatory characteristics to possible future games. Eighteen months after the project's beginning, the data acquisition researchers and the game-focused researchers will meet in the framework of one of the yearly workshops to take place at UT-Dallas.

b) During the second year, the PI will travel to Bonn, Germany (see Budget item E2, year 2), to meet with several researchers at the Interdisciplinary Center for Complex Systems (IZKS) involved in the project. The results of this meeting will be posted on the intranet.

c) In preparation for the Research Project Proposal, the PI established contact with several retirement living centers. Given the competitive nature of each NSF Program Solicitation, it was not appropriate to obtain commitments from these establishments. However, based on their expression of interest, we know that a workshop will take place in the Dallas-Fort Worth Metroplex (probably at the Golden Acres Facilty).

4. Final Meeting

The final meeting of the entire project team will allow for self-assessment. This will also provide the necessary details on whose basis the PI will elaborate and submit the research report to the NSF.

Two special provisions regarding project management need to be made regarding the international partner (IZKS-Bonn, Germany) and the consultant (from the Center for Lifelong Learning and Design, Boulder, CO). Quantified data originating from the project will be expressed in a variety of formats. In order to eventually reach a unified framework, and especially to facilitate understanding of data that translates into a map of possible requirements for a totally new category of games, we expect a mathematical contribution complementary to our own efforts in data acquisition. Past experience and a fruitful collaboration with the IZKS in the expression and interpretation of anticipatory characteristics of extreme events (in which the PI was involved while he was in Germany) resulted in effective procedures for data validation and model building. This requires meeting on a yearly basis with the German counterparts (see Budget item E2, years 1, 3). Given the high profile of the IZKS and the Institute for Applied Mathematics, it is plausible to assume that they will be funded, as they have been in the past. The German colleagues will have access to the website and Intranet. In turn, researchers in the USA will have access to their web-based repository tools.

The entire interaction with the consultant at the Center for Lifelong Learning and Design will be coordinated by the Institute for Research in Anticipatory Systems. A total of ten days of interaction and travel were budgeted (see Budget items G3, E1, years 1, 2, 3), more at the ramp-up state and at the final phase.

At the end of this hopefully-to-be-funded project, we plan to organize a session in the framework of a better established conference (or conferences); or we will organize a conference in the area where team members will present their work and findings. This conference will be open to scientists and scholars from many fields, to business people, and to educators from the USA and abroad. This event will also be transmitted via webcast. Alternatively, this conference might be organized in Europe, if support for such an endeavor will become available through the German partner. What counts is the scientific integrity and the possibility to disseminate the results of the research in order to affect change in society. Aging is not only a USA phenomenon.

Given that the broader project, *Seneludens* (cf. introductory comments to this Project Description) will continue with the focus on game development, behavioral therapy, and the appropriate research of new forms of interaction, new interfaces, and other devices that will engage the aging, the website will be maintained and expanded to cover these aspects. This guarantees that the results obtained will remain accessible to all researchers involved, as well as to other interested parties, for a relatively long duration beyond the end of this project.

First Year	Second Year	Third Year
Brain imaging: experiment design, sample selection, quantification, data analysis, coordination with next phase	Motion Capture: experiment design, sample refinement, quantification, data analysis, coordination with previous phase	Integration of data from brain imaging and motion capture; 15 game development workshops with the aging
Seminar (all participants, plus consultant and foreign partner); NSF Meeting Washington, DC (2 persons); post-Washington evaluation meeting	Mid-term Project (18 months after start): Evaluation of results, fine tuning (coordination among the groups, integration of results and efforts); NSF Meeting Washington, DC; post-Washington evaluation meeting	Game development workshops based on available data from quantified brain imaging and motion capture: Phase 2 of motion capture quantification; new procedures for refining data (student development of 6 coordinate systems and videostream); Conference on the subject of anticipation, aging, and games. Publication of research results

- Web-based coordination and communication tools, including intranet
- Data repository accessible through the intranet
- Report and validation system
- Public domain feedback facility open to interested parties (aging, physicians, gerontologists, social services workers, game developers, etc.)
- Experimental new forms of interaction and game narratives open to public evaluation
- Web publication of progress report; peer-reviewed web publication of reports on research

5. Relation to the Team's Previous Work

Advancing knowledge about anticipatory characteristics is a challenge and a change in perspective. The research team integrates scholars with a solid scientific background and with a good record of publications and sponsored research

The PI (Mihai Nadin), with advanced degrees in engineering and philosophy, logic, and the theory of science, is one of the first scholars to dedicate research to the particular subject of anticipation. The graduate lecture "Minds and Configuration: Intelligence is Process" (1988) reported on research he carried out at Ohio State University during his tenure (endowed chair). The wide interest in the subject led to a book: Mind—Anticipation and Chaos (1991), published in the prestigious series, "Milestones in Thought and Discovery" (Belser Presse, Zurich/Stuttgart). The book established a foundation for the understanding of anticipation from the perspective of dynamic systems theory applied to the mind. (At about the same time, the mathematician Robert Rosen advanced his own ideas based on his work on the mathematical foundation of biology.)

Pursuing research in anticipation at Stanford University (1999), Nadin focused on dynamic systems. Pursuant work in anticipation led to an invitation from Lotfi Zadeh to do research at the BISC Lab at the University of California-Berkeley. Research on integrating anticipation in computation and control mechanisms was also funded through contracts with industry (especially DaimlerChrysler and Audi).

Nadin has written extensively on anticipation. Defining the field as "data rich and theory poor," Nadin published (2003) Anticipation—The End Is Where We Start From, reporting on almost 10 years of research supported by the DFG (the German NSF) and by other prominent European Foundations. He serves on the Editorial Board of Real-Time Systems and is the publisher of the Digital Horizons series (Synchron Publishers, Heidelberg).

Co-PI Sandra Bond Chapman is the Director of the Center of BrainHealth™ at The University of Texas at Dallas. Under her leadership, the Center has developed research programs dedicated to understanding, preserving and healing the brain. The Center's goal is to optimize brain health after brain injury or disease, and to facilitate natural aging across the life span. Chapman's work bridges the gap between research and practice to develop more rapid application of therapies. Her research spans the age spectrum from studies that evaluate plasticity in brain-injured children and adolescents to research focused on understanding the potential for plasticity throughout adulthood into old age. She has developed diagnostic measures and treatment protocols that have shown to be powerful tools in identifying and enhancing cognitive-linguistic function in children and adults with brain injury, stroke, and brain diseases such as Alzheimers and Frontotemporal Dementia, as well as in the healthy brain aging into old age. She also serves as Head of the Focus Group on Diseases of the Aging Brain for the Institute of Biomedical Sciences and Technology at UT Dallas.

Dr. Chapman's research explores relationships among cognitive abilities, discourse function, neurological profiles and intervention as well as drug therapies using structural brain imaging measures (MRI) and functional brain imaging measures (SPECT, fMRI). She has received continuous funding for her research from the National Institute of Health and the National Institute on Aging. She has established rich collaborations with major medical centers across the country. Dr. Chapman has published extensively and is invited to present her research findings and unique clinical approach to enhancing brain function across the country.

Co-PI Dr. B. Prabhakaran has been working in the area of multimedia systems: multimedia databases, authoring & presentation, resource management, and scalable web-based multimedia presentation servers. He has published several research papers in prestigious conferences and journals in this area. Prabhakaran specializes in interactive multimedia strategies for analog and digital servers. He also works on animation databases and their applications using motion mapping and inverse kinematics and has researched development of a toolkit that helps in generation of new animations based on existing ones. He has also worked on partial resolution of fuzzy queries and a Context Free Grammar approach for animation model/motion representation. Dr. Prabhakaran received the NSF CAREER Award FY 2003 for his proposal on Animation Databases. He has served as an Associate Chair of the ACM Multimedia'2003 (November 2003, California), ACM MM 2000, and ACM MM'99 conferences. He has served as guest-editor (special issue on Multimedia Authoring and Presentation) for ACM Multimedia Systems journal. He also serves on the editorial board of Multimedia Tools and Applications journal (Kluwer Academic Publishers).

Co-PI Thomas Linehan is the Director of the Institute for Interactive Arts and Engineering at the University of Texas at Dallas. His academic experience and interest in new research perspectives go back to his role in the Advanced Computing Center at the Ohio State University (1980-1989). His involvement with Motion Capture also goes back to that time and led to spectacular results: the capture of the entire repertory of the world's best known mime Marcel Marceau. This material in itself is a goldmine for the study of anticipation as it relates to a rich repertory of human action. Moreover, Linehan has a solid record of research (most recently on projects of Alcatel), and most important, an exemplary record of involving students and Ph.D. candidates in significant projects.

Co-Pi Thom Gillespie is Director and creator of the MIME program in the department of Telecommunications at Indiana University. MIME is a computer game design program which draws on existing talent and classes from a variety of departments and schools at Indiana University. He is also a Clinical Associate Professor, who brings to the project, as a partner from a program not usually associated with the type of research we are pursuing, a novel perspective on games and game design. He is a member of the Board of Directors for the Museum of the Person in Sao Paolo Brazil, and Consultant for the United Nations Food and Agriculture Organization (in Rome), positions which testify to his interest in the problems of human dynamics today. As a graduate and post-graduate advisor, he works with 35 MA candidates and 5 at the PhD level—and will bring some of their input to the project.

Klaus Truemper is a senior researcher in the project. He developed and implemented (mostly with PhD students) 6 large software systems: Leibniz System for logic programming, which will be used for a new category of applications within this research; Lsquare System for learning logic: Laempel System for textspell, syntax, and semantics checking; Kritzel for handwriting interpretation; OCHEM for exposure management of hazardous materials; FasTrac for tra_c simulation and control. He published 3 books, 40 papers in major journals, 3 book chapters. Among the publications, the most recent, Design of Logic-based Intelligent Systems (Wiley, New York, 2004, 352 pages) is of direct interest to our attempt to fit the data to future games.

Navzer Engineer is a postdoctoral senior member of the team. He got his Ph.D. in Cognition and Neuroscience at UT Dallas and published several very respected articles on a subject very close to this research: plasticity in the auditory cortex. Dr. Navzer Engineer is interested in brain plasticity, aging and, in particular, computer based interactive applications to stimulate brain plasticity.

Consultant Gerhard Fischer is the Director of the Center for LifeLong Learning and Design, a fellow of the institute for Cognitive science (ICS), and professor in the Department of Computer Science, all at the University of Colorado-Boulder. His research interests include: lifelong learning, design, meta-design, software design, creativity, social creativity, distributed intelligence, human-computer interaction, and design-for-all (assistive technologies). Anticipation presents an exciting new perspective to these areas. The goal of the Center for LifeLong Learning and Design is to establish, both by theoretical work and by building prototype systems, the scientific foundations for the construction of intelligent systems that serve as amplifiers of human capabilities (e.g., to expand human memory, augment human reasoning, and facilitate human communication.

Sergio Albeverio, cooperation partner in Germany, is a mathematical physicist with broad interests. During his tenure in Germany, the PI collaborated with Albeverio on mathematical models of anticipation. His current interests lie in the theory of stochastic processes and applications, in particular stochastic analysis and its interactions with partial differential equations, functional analysis, nonstandard analysis and its applications, mathematical modeling (biology, economics, physics, urban studies, traffic). His list of publications is 58 pages long, extending back to 1967, and includes edited books, articles in books and peer-reviewed journals, proceedings, and monographs. The University of Bonn is a research-oriented university—at top of ranking for research in Germany—that cooperates with numerous universities and research establishments around the world. It has developed teaching and research specializations that enjoy worldwide recognition. The School of Mathematics is among the best in Europe. Professor Albeverio is a member of the International Center for Complex Systems. In this framework, he co-chaired the conference on Extreme Events, in which the role of anticipation in dealing with extreme events was a major topic of interest.

6. Current and past NSF Work

The PI taught in Europe for the last 10 years. His record of sponsored research integrates grants from the DFG (German NSF) up to the time when he returned to the USA (being offered an endowed chair UT Dallas).

From the team only Dr. Prabhakaran's work qualified for NSF support and was funded. Current project: CAREER: Animation Databases Location of the Project: University of Texas at Dallas;Amount: $400,000 Duration: 03-08; Summer months: 1.5

Dr. Gerhard Fischer has a very good record of NSF support and a number of ongoing projects. 2004-2005: "SGER: Designing and developing mobile computing infrastructures and architectures to support people with cognitive disabilities and caregivers in authentic everyday tasks", $ 107,000; Sponsor: NSF CISE

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