WHOLE-PERSONALITY EMULATION

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A research study that obtained questionnaire data via mobile communications from 3,267 residents of all 50 US states illustrates how personality capture can be accomplished in a manner suitable for later emulation inside a virtual world or comparable computer system by means of artificial intelligence agents calibrated to match the personality profiles of specific people. This was the most recent step in a research project that had already developed methods for computer administration of massive questionnaires, and it focused on one of the most prominent models of personality, the so-called Big Five dimensions. The key innovation of mobile data collection will allow efficient personality capture at low cost in effort to the individual, and thus with greater ultimate accuracy because of the very large number of diverse measures that can be obtained. Factor analysis of the data shows how it is possible to develop a flexible system for aggregation of measures that can be adapted to emulation across a changing array of environments.

Keywords: personality, Big Five, avatar

Many plausible routes to mind uploading can be imagined, but one is very solidly rooted in existing psychology: the use of massive questionnaires for detailed personality capture, followed by programming artificial intelligence agents to behave according to the personality profile of a given individual human. This approach can achieve near-term success at moderate levels of fidelity, and can be combined with other approaches to achieve increasing fidelity over time. This article reports one series of research studies as an example of the kind of work that can be done today, and as a source of insights about the challenges that must be overcome.

Beginning in 1997 with a website then called The Question Factory, I assembled a very large number of questionnaire items of many types, and programmed them into modules for convenient computer administration, eventually archiving my own responses to over 100,000 items as a feasibility test to determine how many questions an individual could reasonably be expected to answer. In several publications focused on personality capture, I reported results of administering particular large sets of questionnaire items to a few other individuals [Bainbridge, 2003, 2004a, 2004b, 2006, 2011a]. Given that existing personality psychology publications report results of administering standard tests to a few hundred respondents, my own initial priority was working out principles for designing the software that administers the items and analyzes the data, at first using only a few research subjects. The phase of research reported here goes beyond those small numbers of respondents, reporting results from administering 200 items to 3,267 residents of all 50 US states, through the use of a convenient Android application on mobile devices.

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A very large number of reasonably verified psychology questionnaire modules exist, but for the purposes of this study one stands out: the so-called Big Five personality dimensions often described in their OCEAN variant: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism [Wiggins, 1996]. While this analytical system is vulnerable to many different criticisms, it is well established in the literature, and has been the focus of several studies related to computer science. Indeed, the chief criticism is that the Big Five are too global, missing many of the significant details that make each individual personality unique. In the approach followed here, that is not a disadvantage at all, because all the many other psychological measures can be included in any full suite of personality capture software, and the Big Five can serve as a major overarching framework for connecting many of the other measures. That is, in the context of whole-personality emulation, the Big Five can unite the Small Hundred.

1. Personality Capture

At a first approximation, there are two fundamentally different approaches to mind uploading: (1) fine-grained scan of the brain to map the neural connections, followed by computer simulation of that structure, and (2) detailed observation of human behavior, followed by simulation, whether based on machine learning of the behavioral data or on a theory-based analysis. Each of these approaches poses major challenges. For example, it is not clear that the brain can be scanned at the neuronal level without destroying it, and the gross connections between neurons may capture only part of their propensity to interact in various ways. Equivalent problems exist on the behavioral side, such as the question of whether high-precision personality capture would require recording all the stimuli experienced by a person during an entire lifetime, in addition to the individual's responses to those stimuli. Even if only moderate fidelity is required, challenges abound. For example, the approach taken here ignores most of the intellectual skills possessed by an individual, such as those measured by school tests, as well as the episodic memories of a lifetime which could be the basis of an entirely different research program.

The research reported here is a logical development from work in the 1980s to develop educational software to teach students how to do questionnaire survey research, which necessitated programming a system for creating and administering questionnaires on a personal computer [Bainbridge, 1989], as well as on broad experience doing scientific studies with questionnaire data [Bainbridge, 1991]. In the 1990s, the author managed support for the General Social Survey from the National Science Foundation, and in recent years has been a consultant for a major online digital library of survey data, The Association of Religion Data Archives. With the birth of the World Wide Web, it was a logical step to begin using Internet to create as well as to administer questionnaires.

A major step forward was Survey2000, a very large international online questionnaire administered in 1999 [Witte, Amoroso, & Howard, 2000; Witte & Pargas, 2004]. Included was an open-ended question I had prototyped with The Question Factory, asking respondents to write a brief description of some development that might occur over the coming century, and responses from approximately 20,000 people

provided the material for writing 2,000 statements about the future. For example, one rather broad statement was: "There will be artificial intelligence systems that are able to respond to the full experience of the real world." Other statements covered different aspects of a general idea, such as: "Computers will be integrated into the human body." "An electronic interface will allow people to slot programs directly into the brain to learn new skills like a foreign language instantly." "People will have communications devices implanted for a technological form of telepathy or ESP." A software system called The Year 2100 was programmed to administer questionnaire items based on the statements, and analyze the individual's resultant data, working on an ordinary desktop computer and distributed freely over Internet.

In the software, the user rated each statement on two scales: how likely this prediction of the future is to come true, and how good or bad would it be if it did. This dual-response method allows us to see how individual questionnaire items can be built into more complex structures of measurement. For each individual, the data consist of 2,000 pairs of numbers, so it is possible to calculate the statistical correlation between the two sets of 2,000 ratings, which is a measure of the respondent's optimism about the future, normed to that individual's opinions about what would be good or bad. The more positive the correlation coefficient is, the more the individual believes that good things will happen, defining "good" in terms of his or her personal values. Chiefly for convenience, but also analytically, the 2,000 items were presented in 20 sets of 100, for example one concerning outer space and another concerning government. Thus, it is easy to calculate these optimism scores for the 20 separate sets, or any other subsets of items, and a person may be optimistic about the future in space, but pessimistic about the future of government here on Earth.

A second personality capture module called Self was an extension of the classic work on the *semantic differential*, developed in the 1950s by Charles Osgood, asking the respondent to judge something in terms typically of 21 pairs of opposite adjectives [Osgood, Suci, & Tannenbaum, 1957; Osgood, May, & Miron, 1975; Osgood, 1976]. Through a series of studies, using factor analysis and progressively refining the list of antonyms, Osgood came to the conclusion there existed primarily three dimensions of emotional meaning, and 7 of the 21 scales should be devoted to each. *Evaluation* was the first dimension, measured through scales like good-bad, beautiful-ugly, true-false, and kind-cruel. The second dimension, *potency*, emerged in such distinctions as strong-weak, hard-soft, heavy-light, and masculine-feminine. Some respondents have difficulty distinguishing the third dimension, *activity*, from potency, but it was measured by dichotomies like active-passive, fast-slow, and excitable-calm.

Much more recently, David Heise [1999, 2004; Schneider & Heise, 1995] has showed how semantic differential data about a person can be used to emulate aspects of that person's framework of judgment. Of course, it is easy enough to have the individual rate a number of key concepts, such as *mother* and *child*, on a set of semantic differential scales. Heise's key step was to postulate *affect control theory*, a system for predicting how ratings of separate concepts could combine in a particular, novel situation. For example, suppose Heise already has a person's ratings of these four concepts: *mother*, *child*, *tired* and *scold*. His theory then allows him to predict how the person would rate

the entire sentence, “The tired mother scolded her child.” To do so requires development of a kind of grammar, specifying the algorithms for combining the meanings of words into the meanings of sentences. Furthermore, Heise’s approach would allow scientists to evaluate and improve the theory, on the basis of any discrepancies between such predictions and actual ratings of whole sentences. Central to Heise’s research program was the use of personal computers to allow people to invest many hours rating a large number of concepts in terms of the semantic differential, doing so in short bursts of activity whenever they happened to have time during the day. Inspired by this methodological innovation, I turned the method around, to get people to construct very large scales comparable to the semantic differential, with hundreds of dichotomies rather than just one or two dozen.

With the help of 36 students in classes on the Sociology of Organizations and on Small Group Processes, and consulting four standard thesauri, I identified 800 pairs of antonyms that could describe a person. In the Self software system, each item was just a single word, and the software unobtrusively kept track of antonym linkages that connected the 1,600 words into pairs. Respondents were asked two questions about each word: one about how good or bad it was to have a given personal characteristic and thus directly invoking the evaluation dimension, and the other asking how much the respondent possessed that characteristic. The correlation between the two sets of numbers reflected the person’s self-esteem, normed to that individual’s values, and again the terms were arranged in 20 rough categories, each of which could produce its own self-esteem score.

In performing personality capture, it is important to motivate the person, although doing so in a manner that minimizes distortions during the data collection process. With all self-rating measurement instruments, there are issues of response biases, including social desirability bias. As a first step toward dealing with this, the Self software provided complex analytical feedback - all kinds of statistics and printouts, including a little automatically constructed essay about each of the 20 categories - but withheld that feedback until the respondent had answered the questions. To illustrate the danger of such biases, and to illustrate how the system worked, here is one part of the output for an individual who has a high valuation of his or her own intellect, an aspect of the person often associated with the Openness dimension of the Big Five:

> What is your self-image in the general area of “intellect” qualities? Are you mentally active or inactive, aware or unaware?
>
> Your self-image has 34 of the qualities in this group: lucid, logical, unrealistic, sharp, perceptive, knowledgeable, clever, scientific, articulate, educated, witty, adept, proficient, imaginative, inquisitive, astute, bright, informed, insightful, enlightened, intelligent, rational, philosophical, aware, sane, sophisticated, intellectual, inventive, conscious, discerning, expert, thoughtful, deep and smart.
>
> The opposites of these qualities are: murky, contradictory, realistic, dull, opinionated, ignorant, blundering, unscientific, inarticulate, uneducated, witless, inept, deficient, unimaginative, uninquisitive, naive, dim, unacquainted,

muddled, unenlightened, unintelligent, irrational, shortsighted, unaware, insane, unsophisticated, unintellectual, uninventive, unconscious, stupid, amateur, thoughtless, shallow and dumb.

On average you judge your 34 intellect qualities to be 6.6 on the scale from bad=1 to good=8. Roughly speaking, you feel these qualities are very good.

Your self-esteem is measured by the correlation between rating qualities good and saying that you have them. With respect to "intellect" qualities, your self-esteem is 0.92. That is, you have extremely high self-esteem!

You rated all 40 pairs of opposites. The average difference in your rating of the antonyms in each pair was 3.3 on the 8-point Little to Much scale. This is a moderate difference. Your qualities in this area are somewhat clear.

On the 8-point Bad to Good scale, the average difference in your rating of the antonyms in each pair was 3.4. Your values are rather clear, but not striking, when it comes to "intellect" qualities.

Clearly, the individual's self-perception is an important part of personality, and an output like this could be compared with the person's actual performance on intelligence tests and other more objective measures. Any gap between the individual's self-image and the results of objective tests would be further information about that individual's personality. The promising results from this experiment in extending the semantic differential suggested that other existing measurement techniques should also be explored, especially those used by psychologists of personality.

2. The Big Five

Research using questionnaires to explore personality began prior to the Second World War, but immediately after it this approach blossomed, especially through the work of Raymond Cattell who claimed to have discovered fully sixteen primary dimensions of personality [Cattell, 1948, 1949]. Although a version of Cattell's questionnaire test was still being used sixty years after its creation, his specific findings were never replicated by other psychologists, and one reason may be the primitive nature of computing technology at the time he worked. He employed a computationally-intensive form of statistical analysis called *factor analysis*, which ideally is used iteratively, in a process by which the items in a questionnaire are constantly refined through continual reanalysis, and which placed very heavy demands on computing power, at least during the early years of digital computers [Cattell, 1965a, 1965b]. Of course modern computers have no difficulty with factor analysis, and if it were being invented today we might classify it as a variety of machine learning.

Factor analysis is not only demanding, but also makes very definite assumptions about the structure of reality. It begins with responses from a few hundred people who filled out a personality questionnaire containing from a dozen to several dozen items. It then calculates the correlations among all pairs of items, using the Pearson's r correlation coefficient which assumes the items have particular qualities such as being real-number

variables with a normal distribution of cases. Then it goes through a series of steps, including a crucial iterative process called *rotation*, to arrive at a smaller number of new variables called *factors*, each of which represents a dimension of variation across all of the original items.

While many psychologists criticized Cattell's specific findings, many adopted his general methods. The gradual result was consolidation on five key dimensions of personality, the so-called "Big Five" personality dimensions that are central to personality psychology. Many psychological tests are protected by copyright, but Lewis R. Goldberg has been a pioneer of creating and validating versions of psychological scales, then placing them in the public domain for anybody to use [Goldberg, 1993, 1999]. A leading Big Five researcher, Goldberg offers 100 Big Five items, 20 measuring each of the five dimensions. Each item is a phrase describing a characteristic a person might have. The respondent rates each item in terms of how accurately it describes him or her, using a 5-point scale from 1 to 5. Here are Goldberg's Big Five, in the order he lists them, along with two characteristics from the dimension's list of twenty items [http://ipip.ori.org/newBigFive5broadKey.htm]. The second example for each dimension is scored negatively:

Extraversion:
+ Make friends easily
– Am a very private person

Agreeableness:
+ Sympathize with others' feelings
– Am indifferent to the feelings of others

Conscientiousness:
+ Love order and regularity
– Find it difficult to get down to work

Emotional Stability (opposite of Neuroticism in OCEAN):
+ Am relaxed most of the time
– Get stressed out easily

Imagination (comparable to Openness in OCEAN and often called Intellect):
+ Love to think up new ways of doing things
– Have difficulty understanding abstract ideas

Some of these scales have very long histories in psychology, especially the first one, Extraversion, sometimes also called *surgency*. It features prominently in the 1921 classification of personalities offered by Carl Gustav Jung, Sigmund Freud's early disciple and later rival [Jung, 1923]. Jung, in turn derived some of his ideas about personality types from Friedrich Nietzsche's 1872 book, *The Birth of Tragedy*, and Nietzsche looked to the ancient Greeks for inspiration [Bishop, 1995].

To create the new Windows-based software module called Self II, I took the 100 descriptors used by Goldberg to measure the Big Five, plus 1,900 others he created and placed in the public domain to emulate other standard personality tests. As in the original Self module, the respondent rates each descriptor in terms of how well it describes the

respondent, and how good it is to have this quality. So the module collects 4,000 pieces of data, two for each of the 2,000 stimuli. Table 1 shows the mean Little-Much and Bad-Good scores for one individual, for three different version of the Big Five, the OCEAN version, Goldberg's version, and an alternate version Goldberg developed with more factors, including a "Negative Valence" factor that handles some of the social desirability bias by pulling out the effect of negative evaluations. The ratings are means on an 8-point scale: Little = 1 to Much = 8 and Bad = 1 to Good = 8.

Table 1: Mean responses by one subject to three personality models in Self II

Personality factor	How MUCH the quality describes the respondent	How GOOD the respondent judges the quality to be
The OCEAN version of the Big Five		
Openness to Experience	5.60	5.70
Conscientiousness	4.60	6.10
Extraversion	3.75	5.15
Agreeableness	4.15	4.45
Non-Neuroticism	3.85	5.50
Lewis Goldberg's version of the Big Five		
Intellect	6.60	6.60
Conscientiousness	4.85	5.55
Extraversion	3.65	5.25
Agreeableness	3.80	4.30
Emotional Stability	4.25	5.30
An Alternate Model		
Intellect	6.60	6.40
Conscientiousness	5.20	4.70
Extraversion	3.80	5.20
Agreeableness	4.00	4.60
Emotional Stability	4.00	5.70
Attractiveness	4.60	5.80
Negative Valence	4.80	4.50

Note that in all three systems, which use somewhat different specific descriptors, the respondent scores low on extraversion, but does not consider extraversion to be bad, rating it above agreeableness in each case on the bad-good scales. Apparently this respondent would wish to be more extraverted. Other people will display different patterns, and the key point is that the Big Five need not be oversimplifications, but can display considerable complexity, even before we begin to connect them to wholly different measures, like the ones developed in the original Self program. The fact that different well-validated versions of the Big Five exist also suggests they are not straightjackets for the mind, but flexible tools to encompass human complexity, through over-arching concepts that can connect many specific measures. Given the existence of high-performance computers, this complexity need not be a burden, but inspires us to develop methods for extracting the greatest value from it.

3. Android App

After both Self programs had been completed, an opportunity presented itself to explore a novel method for collecting personality capture data, in the new mobile computing environment. My first step in that direction had been programming for a pocket computer a variant of another module I had developed, Emotions, that was based on 2,000 events that might occur in a person's life [Bainbridge, 2008]. These event descriptors had been collected through online questionnaires that asked people to nominate things that would make them feel each of 20 specified emotions, and through scanning online novels for those emotion words to see what events had triggered them in the author's narrative. The Emotions program presented the stimuli in 20 groups, each associated with one of the emotions, asking: (1) how bad or good would it be to experience each event, and (2) how much would the event generate the specified emotion in the respondent. For the mobile computer version, the respondent was asked to rate each of the 2,000 events in terms of all 20 emotions, for a total of 40,000 ratings rather than just 4,000. The respondent found it quite comfortable to answer this vast number of questions, because the pocket computer allowed answering a few at a time, while waiting for a bus or during some other wasted time during the day, wherever the respondent happened to be. Rather than being a burden, this task turned out to be an antidote to boredom, given that every life has lots of down time during which the person wishes something more interesting were available.

The new research opportunity came when Martine Rothblatt of the Terasem Movement asked one of his associates, Michael Clancy, to transform Self II into an Android application, and a version of the program using just Goldberg's 100 Big Five items was distributed for free over Internet at http://www.personalitymd.com. On its website at http://www.terasemcentral.org, the movement describes itself thus: "Terasem Movement, Inc. is a 501c3 not-for-profit charity endowed for the purpose of educating the public on the practicality and necessity of greatly extending human life, consistent with diversity and unity, via geoethical nanotechnology and personal cyberconsciousness, concentrating in particular on facilitating revivals from biostasis. The Movement focuses on preserving, evoking, reviving and downloading human consciousness."

I did not myself create the app or collect the data, but was always happy to provide my source code to fellow researchers. As programmed expertly by Clancy, the application worked very well, allowing the respondents to send the data to the central archive instantly, rather than needing to plug their device physically into their desktop computer and go through the steps of downloading the file, as was required in the mobile version of the Emotions program. In addition to the 200 bytes of data in which a respondent rated the Big Five items twice, the dataset included two measures of the respondent's location: (1) a text field where the respondent wrote this information, and (2) the latitude and longitude automatically provided by the respondent's device, if the respondent has allowed it to do so. Most respondents lived in the United States, and the data reported here were for the 50 US states, cases in which the two geolocators agreed. Geolocation could be of importance in the future, as individuals send vast numbers of questionnaire ratings through such a system, over a period of years, including for example the emotional rating of events as they happen in the real world. Also, we can

use geolocators to look at regional cultures and other local conditions that shape people's experiences of life, such as rural versus urban environments

Clancy was able to provide the data in a form requiring very little preprocessing before placing it in a standard statistical analysis program. The chief preparation necessary was calculating the correlations for all respondents between the two sets of responses to the 100 Big Five items, because statistical analysis packages do not calculate correlations within rows of the data. For the 3,267 respondents whose data are reported here, there was a mean correlation of 0.43 and a standard deviation of 0.34. Correlation coefficients range from -1.00 to +1.00, so 0.43 implies positive self-esteem for the typical respondent: The person's rating of how much he or she has each quality correlates positively with judging the quality to be good. However, this correlation may also reflect response biases such as *acquiescence* [Couch & Kenniston, 1960] or *social desirability* [Edwards, 1967].

A standard deviation of 0.34 implies that about a sixth of respondents have correlations below 0.43 - 0.34 = 0.09, which suggests lack of self-esteem, so there is ample scope for future analysis of how the two sets of measures correlate. Here we shall focus on the first set, people's descriptions of themselves, to replicate the classic factor analyses as both a quality check and an opportunity to explore the complexity of personality with an unusually large number of respondents. There are many kinds of factor analysis, but one key distinction is between confirmatory and exploratory approaches.

A *confirmatory factor analysis* starts with a theory and seeks to test it. In this case, that meant telling the computer to reduce the data on people's ratings of themselves to exactly five dimensions, and indeed Goldberg's version of the Big Five did emerge. However, as the differences among the three models of personality in Table 1 suggest would happen, the results were not exactly his. Notably, the first factor was the opposite of his Emotional Stability factor. Table 2 lists the items with the strongest loadings on this factor. The items are numbered in terms of their order of appearance in the questionnaire. A factor loading can be conceptualized roughly as the correlation between the item and the factor, although the numbers tend to be larger than ordinary correlations. Originally, the Non-Neuroticism factor of the OCEAN version was called the Neuroticism factor, but was renamed by psychologists and its codings reversed, so that a high rating on each factor was socially desirable. But here, our 3,267 respondents have returned us to the original meaning of this factor.

Table 2: Confirmatory factor 1: Neuroticism (3,267 respondents)

Factor 1 Item	Loading
49. Get irritated easily	0.72
64. Get angry easily	0.72
68. Have frequent mood swings	0.72
43. Get upset easily	0.71
62. Get stressed out easily	0.69

81. Panic easily	0.65
48. Change my mood a lot	0.65
79. Get overwhelmed by emotions	0.65
65. Get caught up in my problems	0.64
71. Am easily disturbed	0.63
26. Take offense easily	0.60
89. Often feel blue	0.60
20. Worry about things	0.50

An *exploratory factor analysis* seeks to discover meaningful structures without many preconceptions about what they will be. I asked the computer to do a factor analysis of people's ratings of themselves, without specifying how many factors there should be. Technically, this meant using principal components analysis, selecting for rotation all factors with eigenvalues greater than 1, and using the varimax rotation method. Table 3 shows the rather complex results, which can be called the Small Fifteen. The numbers in parentheses are the factor loadings of the particular items.

Table 3: Fifteen dimensions of personality (3,267 respondents)

1. Extraversion	POSITIVE: Start conversations (0.70); Am the life of the party (0.70); Talk to a lot of different people at parties (0.70); Feel comfortable around people (0.66); Don't mind being the center of attention (0.63); Feel at ease with people (0.62); Make friends easily (0.62); Am skilled in handling social situations (0.61). NEGATIVE: Have little to say (-0.55); Often feel uncomfortable around others (-0.56); Find it difficult to approach others (-0.61); Don't talk a lot (-0.64); Keep in the background (-0.66); Am quiet around strangers (-0.66).
2. Neuroticism	Have frequent mood swings (0.74); Get stressed out easily (0.74); Get irritated easily (0.73); Get upset easily (0.72); Get angry easily (0.70); Get caught up in my problems (0.67); Get overwhelmed by emotions (0.67); Change my mood a lot (0.66); Panic easily (0.66); Often feel blue (0.61); Take offense easily (0.59); Am easily disturbed (0.59); Worry about things (0.54).
3. Benevolence	Sympathize with others' feelings (0.71); Think of others first (0.69); Take time out for others (0.66); Love to help others (0.66); Inquire about others' well-being (0.64); Feel others' emotions (0.62); Have a soft heart (0.59); Know how to comfort others (0.57); Have a good word for everyone (0.50).
4. Intellect I	Am quick to understand things (0.71); Catch on to things quickly (0.62); Can handle a lot of information (0.62); Am good at many things (0.60); Pay attention to details (0.56).
5. Organization	Do things according to a plan (0.75); Follow a schedule (0.70); Make plans and stick to them (0.68); Love order and regularity (0.63); Am always prepared (0.52); Like order (0.52).
6. Messiness	POSITIVE: Leave a mess in my room (0.71); Leave my belongings around (0.70); Often forget to put things back in their proper place (0.69). NEGATIVE: Like to tidy up (-0.62).
7. Indifference	Am indifferent to the feelings of others (0.59); Feel little concern for others (0.57); Am not interested in other people's problems (0.55).
8. Unimaginativeness	POSITIVE: Have difficulty imagining things (0.71); Do not have a good imagination (0.63). NEGATIVE: Have a vivid imagination (-0.61).
9. Literacy	POSITIVE: Have a rich vocabulary (0.73); Use difficult words (0.73); Love to read

	challenging material (0.65). NEGATIVE: Avoid difficult reading material (-0.53).
10. Laziness	Find it difficult to get down to work (0.58); Neglect my duties (0.58); Waste my time (0.58).
11. Implacability	Seldom get mad (0.74); Rarely get irritated (0.66).
12. Agreeableness	Am on good terms with nearly everyone (0.55); Make people feel at ease (0.50).
13. Inhibition	Bottle up my feelings (0.61).
14. Intellect II	Am exacting in my work (0.55); Love to think up new ways of doing things (0.55).
15. Superficiality	Will not probe deeply into a subject (0.56); Try to avoid complex people (0.52).

The iterative parts of the analysis, which can be classified as machine learning, converged very quickly, perhaps a testimony to how well a large number of respondents compensates for measurement errors in the data. The result was fully 17 factors, of which the last two were essentially noise. Thus, the table lists 15 factors, and I have attempted to label each. All items with factor loadings above 0.5 are included. A negative loading means that the opposite of the descriptor belongs to the factor. For example, the positively loaded items in factor 1 represent extraversion, whereas the negative ones represent introversion.

Clearly, the Big Five have expanded into 15 smaller measures, some of which would require further development for future use, finding other items to combine with the ones listed to do a better job of measuring the quality. As in the third version of the Big Five in Table 1, this approach to some extent handled the negative valence, by producing some factors that were distinctively negative in connotation. In future, one could add to the questionnaire one of the response bias measures that can be used to control for such things as social desirability - but with awareness that social desirability bias is not so much a defect of questionnaire items as a dimension of individual personality that needs to be measured in its own right.

Factor 13, which I call Inhibition, consists of just one item, “Bottle up my feelings,” and it is a good example of how we can go beyond these summary measures. I suspect that people differ in whether they interpret bottling up to be a bad thing, although the subculture of psychotherapists has a vested interest in calling it bad. We can learn more by listing all the other items that correlated at lest 0.25 with this item: Am a very private person (0.31), Am quiet around strangers (0.30), Keep in the background (0.27), Often feel uncomfortable around others (0.26), Don’t talk a lot (0.26), Find it difficult to approach others (0.25), Have little to say (0.25), and Often feel blue (0.25). Some of these seem obviously negative, even reflecting depression, but the first three and some of the others are not necessarily negative. Especially in some cultures, but also in many people’s experience of life, being a quiet person can be the best choice. To the extent that the Big Five represent a constraining orthodoxy, it is because they reflect the values shared by most people in our society - or most academic psychologists - but once we allow the Big Five to expand into the Small Fifteen, and we collect data from thousands of individuals, then there is ample room for the values of different subcultures to be represented.

4. Emulation

Clearly, it is feasible to apply the new mobile computer and communications technologies to accomplish personality capture in a way that provides much more detail than previously possible, but which also can provide intellectual structure for comprehending the complexity of human personality. How, then, can we take the next step, toward emulating personalities inside the computer? While we can imagine many approaches, some progress has actually been made in one area: designing artificial intelligence systems to operate non-player characters in computer games. My research in the area called *virtual worlds* [Bainbridge, 2007], has primarily been observational, rather than experimentally programming such characters, but I have experimented with programming intelligent agents in non-graphic multi-agent systems [Bainbridge, 2006]

Consider the following very simple scenario, similar to situations commonly experienced in gameworlds like *World of Warcraft* [Bainbridge, 2010a, 2010b, 2010c, 2011b]. Your avatar enters a field, where there are three animals, a wolf, a cow, and a rabbit. When you near the wolf it spontaneously attacks you. When you near the cow, it ignores you. But if you hit the cow, it will attack you. The rabbit either ignores you or runs away, but will not attack under any circumstances. Through very simple programming the animals have been given three different "personalities." Some humanoid non-player characters have been given slightly more complex personalities, for example fighting you aggressively until they see they are losing, and then going into a panic and running away.

Many gameworlds allow certain kinds of avatars to have one secondary avatar, often a hunting animal called a *pet* assisting a hunter, notably *World of Warcraft* and *Lord of the Rings Online*. Others permit entire teams of as many as a half dozen secondary avatars, including *Age of Conan*, *Star Trek Online*, *Dungeons and Dragons Online*, *Gods and Heroes: Rome Rising*, and *Guild Wars*, among the ones I have studied extensively. The relevant point here is that the secondary avatars are semi-autonomous, behaving in combat more or less the way the user has specified, but making decisions on their own from moment to moment, following simple artificial intelligence protocols.

Typically, gamers distinguish three rough categories of avatar in terms of the roles they play in groups: (1) *tank* which engages the enemy in melee combat and monopolizes the enemy's attention, (2) *healer* who stands back and supports the tank by repairing damage done by the enemy, and (3) *DPS* (damage per second) who uses missile weapons to damage the enemy unobtrusively from afar. These could be described as three different personality types: tough and aggressive, meek and nurturant, aloof and precise. However, each secondary avatar could be adjusted to behave as the player would in that role, emulating those aspects of the player's multidimensional personality.

A number of researchers have attempted to design rather more complex virtual characters following one or more of the Big Five personality dimensions [Kshirsagar & Magnenat-Thalmann, 2002; Su, Pham, & Wardhani, 2007]. Consider the list of characteristics in Table 3; some of them are relatively easy to model. A crude way to program "Panic easily" into a gameworld character would be to adjust how much damage the character must receive before it runs away from a fight. An easily panicked character would run earlier than the average character. "Get angry easily" could be modeled by

having the wolf attack as your avatar approached, but when the avatar was still rather far away, or as actually happens with some *World of Warcraft* enemies, flying into an especially violent rage when significantly damaged, rather than running away.

Factor 10 in Table 3, "Laziness," includes "Waste my time." Some non-player characters in *World of Warcraft* are guards who patrol specific routes, for example around a castle, with the duty of attacking any enemies they encounter. One could be programmed to pause and sit down at random, or to wander off the route and inspect any nearby flowers, thus wasting time. In *Lord of the Rings Online*, secondary avatar pets sometimes fail to respond to the player's commands, and this could be interpreted as laziness. While these ideas are simple, in each case the program could use a probability for each behavior based on the score a real human being achieved on the related psychological scale.

Much more complex and refined systems are possible at today's level in artificial intelligence. An example relevant to this study is the work by Kathryn Merrick and Mary Lou Maher [2009], to develop methods to endow gameworld AI agents with curiosity. Although not directly inspired by the Big Five theory of personality, this work is a fundamental attempt to model its Openness dimension, which is often called "openness to experience." This is actually the most controversial of the Big Five, and Goldberg calls it "Imagination" or "Intellect." The debate relates to two somewhat different philosophies of developing personality models: (1) develop a model that distinguishes personality from other metal attributes, versus (2) develop a comprehensive model. In developing their models by means of statistical scaling techniques, some psychologists tried to develop models that were gender-neutral and independent of skill measures such as intelligence, and there have also been issues about whether or how to achieve political neutrality. Arguably, the Openness dimension may implicitly measure intelligence (IQ) and political liberalism. However, for our purposes this may not be a flaw, as a comprehensive personality capture approach would naturally include IQ tests as well as many other measures of aptitude, skill and knowledge. It would also include a vast number of opinion measures, including standard scales from political science.

The exploratory factor analysis in Table 3 suggests one of many possible methods for adjusting the degree of aggregation of personality measures in realtime. Once the data had been entered, and the commands given to the software for the particular analysis, the calculations took only a second or two. Thus one can imagine incorporating factor analysis - or some comparable machine learning method - into an artificial intelligence program. When the avatar entered a scene, such as entering that field and seeing the three animals, the system would automatically adjust to the context, activating a model of the avatar's personality appropriate to the situation.

Factor analysis is a good example, because the number of factors can be adjusted. In the confirmatory factor analysis, the computer was told to produce five factors. But it could just as easily been told to produce seven, if we were interested in Goldberg's alternative Big Seven. Had we requested 17 factors, we would have gotten something like the Small Fifteen that resulted from the exploratory factor analysis. We could have specified any number of factors, from as few as two up to a hundred, and the hundred factors would simply be the hundred items we started with.

The expression Small Hundred refers however to the potential to expand the personality capture and emulation system, as in Self II, to include all the many other standard psychological measures, which are unrelated to the Big Five, but which describe personality. The best example with which to conclude is David McClelland's [1961] three-dimensional model of fundamental motivational orientation: Need for Achievement, Need for Affiliation, and Need for Power. Perhaps coincidentally, in the most influential theory of motivation for players of online role-playing games, Richard Bartle [2004] proposed four motivations, three of which map almost perfectly onto McClelland's dimensions: 1. achievement within the game context (achievers); 2. socializing with others (socializers); 3. imposition upon others (killers). Bartle's fourth dimension is similar to Openness of the Big Five: 4. exploration of the game (explorers). Much work would be required to develop emulation methods for each of these, but the clarity of the concepts is a good starting point.

The most sophisticated existing gameworlds, notably *World of Warcraft*, already award points for a range of behaviors that can be categorized in terms of Bartle's scheme. Experience points can be gained for completing quests (achievers), defeating enemies (killers), and entering new virtual territories (explorers). Players gain reputation points with fictional societies, join social guilds with other players, and exchange communications with others (socializers). Given data about the motivations of a given player, it should be possible to develop a decision model that produces a probability of one versus another action, based on the points to be gained in each as multiplied by a coefficient expressing the person's valuation of the particular kind of point. Thus, when an artificial intelligence agent enters that field, it could calculate whether to earn killer points by attacking the wolf, or explorer points by ignoring the wolf and walking off into the woods.

5. Conclusion

The fact that questionnaire research on personality is so very well developed means that most future research in this area will need to focus on three related challenges: First, we will need to determine which additional questionnaires items will best add breadth and precision to a limited set of items like the 100 measuring the Big Five. As noted above, we have tens of thousands of items to choose from, and motivated people will have no difficulty responding to a few thousand using mobile devices, during moments of inactivity as they go about their daily lives. But we need to determine which questions are really worth asking, and how best to combine them into measurement scales that add meaningful detail.

Second, we can expand our measurement techniques far beyond questionnaires. Robert McCrae and Paul Costa [1996] have suggested there are five categories of data that can define an individual person: 1. basic tendencies (genetics; physical characteristics; cognitive capacities; physiological drives; focal vulnerabilities; personality traits), 2. characteristic adaptations (acquired competencies; attitudes, beliefs, and goals; learned behaviors; interpersonal adaptations), 3. self-concept (implicit and

explicit views of self; self-esteem; identity; life story, personal myth), 4. objective biography (overt behavior; stream of consciousness; life course), and 5. external influences (developmental influences; macroenvironment; microenvironment). Note that personality traits are merely a subcategory in this scheme. Questionnaires can be used to measure attitudes, beliefs, and explicit views of self, but cognitive capacities and acquired competencies would require tests designed to measure them realistically.

A very interesting possibility is that life course and environmental influences could be captured in entirely new ways, automatically by the mobile devices that people have begun to carry through life, by integrating context-aware sensors into them. The Siri system already incorporated in the newest Apple devices employs sophisticated natural language processing, which could in principle document every word the user speaks, and upload it into a personal archive where it is combined with every word of text the individual writes. However, a coherent analytical framework would be needed to cull the valuable information from the noise, and here the traditional questionnaire methods could be very helpful. They are based on language, after all, organizing words and phrases into measurement scales and dimensions, which could then be applied to all the speech and writing produced or perceived by the user.

Third, we need to develop the algorithms to accomplish the computer emulation part of the work. Already, leading researchers who study online virtual worlds have begun to combine questionnaire data with observational data about behavior by the avatars of the respondents [Williams, *et al*., 2009], a kind of environment where field testing of algorithms is especially practical. The current economic realities of online games do not place a high priority on sophistication of artificial intelligence agents, although academic scientists in some numbers are exploring aspects of the problem. Thus, rapid progress appears possible at the present time, but probably requires dedicated funding within a major scientific initiative.

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Table 1: Mean responses by one subject to three personality models in Self II

Personality factor	How MUCH the quality describes the respondent	How GOOD the respondent judges the quality to be
The OCEAN version of the Big Five		
Openness to Experience	5.60	5.70
Conscientiousness	4.60	6.10
Extraversion	3.75	5.15
Agreeableness	4.15	4.45
Non-Neuroticism	3.85	5.50
Lewis Goldberg's version of the Big Five		
Intellect	6.60	6.60
Conscientiousness	4.85	5.55
Extraversion	3.65	5.25
Agreeableness	3.80	4.30
Emotional Stability	4.25	5.30
An Alternate Model		
Intellect	6.60	6.40
Conscientiousness	5.20	4.70
Extraversion	3.80	5.20
Agreeableness	4.00	4.60
Emotional Stability	4.00	5.70
Attractiveness	4.60	5.80
Negative Valence	4.80	4.50

Table 2: Confirmatory factor 1: Neuroticism (3,267 respondents)

Factor 1 Item	Loading
49. Get irritated easily	0.72
64. Get angry easily	0.72
68. Have frequent mood swings	0.72
43. Get upset easily	0.71
62. Get stressed out easily	0.69
81. Panic easily	0.65
48. Change my mood a lot	0.65
79. Get overwhelmed by emotions	0.65
65. Get caught up in my problems	0.64
71. Am easily disturbed	0.63
26. Take offense easily	0.60
89. Often feel blue	0.60
20. Worry about things	0.50

Table 3: Fifteen dimensions of personality (3,267 respondents)

1. Extraversion	POSITIVE: Start conversations (0.70); Am the life of the party (0.70); Talk to a lot of different people at parties (0.70); Feel comfortable around people (0.66); Don't mind being the center of attention (0.63); Feel at ease with people (0.62); Make friends easily (0.62); Am skilled in handling social situations (0.61). NEGATIVE: Have little to say (-0.55); Often feel uncomfortable around others (-0.56); Find it difficult to approach others (-0.61); Don't talk a lot (-0.64); Keep in the background (-0.66); Am quiet around strangers (-0.66).
2. Neuroticism	Have frequent mood swings (0.74); Get stressed out easily (0.74); Get irritated easily (0.73); Get upset easily (0.72); Get angry easily (0.70); Get caught up in my problems (0.67); Get overwhelmed by emotions (0.67); Change my mood a lot (0.66); Panic easily (0.66); Often feel blue (0.61); Take offense easily (0.59); Am easily disturbed (0.59); Worry about things (0.54).
3. Benevolence	Sympathize with others' feelings (0.71); Think of others first (0.69); Take time out for others (0.66); Love to help others (0.66); Inquire about others' well-being (0.64); Feel others' emotions (0.62); Have a soft heart (0.59); Know how to comfort others (0.57); Have a good word for everyone (0.50).
4. Intellect I	Am quick to understand things (0.71); Catch on to things quickly (0.62); Can handle a lot of information (0.62); Am good at many things (0.60); Pay attention to details (0.56).
5. Organization	Do things according to a plan (0.75); Follow a schedule (0.70); Make plans and stick to them (0.68); Love order and regularity (0.63); Am always prepared (0.52); Like order (0.52).
6. Messiness	POSITIVE: Leave a mess in my room (0.71); Leave my belongings around (0.70); Often forget to put things back in their proper place (0.69). NEGATIVE: Like to tidy up (-0.62).
7. Indifference	Am indifferent to the feelings of others (0.59); Feel little concern for others (0.57); Am not interested in other people's problems (0.55).
8. Unimaginativeness	POSITIVE: Have difficulty imagining things (0.71); Do not have a good imagination (0.63). NEGATIVE: Have a vivid imagination (-0.61).
9. Literacy	POSITIVE: Have a rich vocabulary (0.73); Use difficult words (0.73); Love to read challenging material (0.65). NEGATIVE: Avoid difficult reading material (-0.53).
10. Laziness	Find it difficult to get down to work (0.58); Neglect my duties (0.58); Waste my time (0.58).
11. Implacability	Seldom get mad (0.74); Rarely get irritated (0.66).
12. Agreeableness	Am on good terms with nearly everyone (0.55); Make people feel at ease (0.50).
13. Inhibition	Bottle up my feelings (0.61).
14. Intellect II	Am exacting in my work (0.55); Love to think up new ways of doing things (0.55).
15. Superficiality	Will not probe deeply into a subject (0.56); Try to avoid complex people (0.52).