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Individuation: the $N = 1$ revolution

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This commentary looks to evaluate the opportunities that are offered by the differences between individuals and how a focus on this issue will influence the future design of all human–machine systems. It is probable that a continuing increase in computational power and associated memory storage capacities will lead to circumstances in which each and every single person can be coded as, and treated as, a separate individual and therefore not necessarily as a representative part of any group, sample or population. This ascending focus on the individual will serve to subdue the demand for nomothetic pronouncements and encourage the use of idiographic case representations. Arguably, this is a trend that is already being witnessed. A fully achieved state of this focus on the individual, or 'individuation' as it has been termed here, will have important impacts on research in the social, psychological and neurosciences, as well as assessment in all studies of living beings. This tide of progress may be inhibited by proximal economic constraints but equally it may well be advanced by the political imperatives of the times.

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1. The millennium and the melting moments

The recent end of the millennium was an important benchmark in human affairs. Around this social watershed the emphasis in the science of human factors and ergonomics, as well as that in many of the other life sciences beyond, showed change from statements primarily about the 'average' behaviour across individuals to statements about specific instances of the momentary behaviour of one single individual. This changing perspective is well represented, for example, in one of the current set of papers included in this special issue. Here, Parasuraman (2009) has sought to throw light on the genetic bases of individual differences and to show how such knowledge can illuminate the chain that links the molecular to the macro level of behaviour. Indeed, the partnership of psychology, neuroscience and molecular genetics is well on its way to supplying important insights into how specific individuals perform their own personal and very complex acts of cognition (see also Miller *et al.* (2002)). Parasuraman (2009) himself has drawn from various disciplines to trace differing levels of individual performance back to their genetic origins.

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He affirms that these abilities are associated with unique and specific genotypes. This idea contributes further support to the proposition that cognition has a very strong and evident foundation in biology and that individual differences in these cognitive abilities are therefore due to a person's singular genetic composition. However, Parasuraman is also careful to emphasise the dynamics of such conditions, with the nuances of environmental context and momentary gene expression interacting to produce individual cases. Integration across these differing levels of analysis truly promises to provide unique insights into the characteristics of each machine user and system operator.

The evolution toward purely individualistic studies inevitably affects how research data are interpreted beyond the lens of descriptive and inferential statistics. The traditional statistical approach has overwhelmingly emphasised the use of the first two distributional moments of central tendency and variation (but see Newell and Hancock (1984)). The growth of an emphasis on the specific individual would serve to slowly dissipate these studies of distributional characteristics. Although this stage has certainly not been reached, when such a process of dissipation or 'melting' has reached its final fruition, the primary focus of research would be on each and every individual and not on their response as part of any group, sample or even population. If this occurs, the stage of what has been termed individuation will have been reached (Hancock 2003). (The term 'individuation' is used in several contexts ranging from the observations of Nietzsche to those of Jung. While these are allied thoughts on the nature of the individual and the collective, the focus here is more on how humans can be treated and coded in any human–machine system. Especially, the present authors are concerned with what such an analysis means for the design and operations of such systems.)

However, individuation is an end state and there are many intermediate stages along this potential line of research development. In human–machine systems terms, one such step in the mergence of customisation is being witnessed.

As a process, customisation is nicely explored in the present special issue by Baldwin's (2009) article. Here, she examines the safety and efficiency in the design of an everyday vehicular-based system to be employed by a widespread and diverse group of users. Design goals to serve diversity are most easily attained through an understanding of individual differences and in the capacities needed. In the case of successful navigation, such capacities include perception via different sensory modalities, verbal vs. visuo-spatial working memory capacity as well as moderators such as maturational age. Following the results of several experiments examining these issues, Baldwin is able to confirm that individual differences are critical to the design and fabrication of a safe system. This conclusion implies that, in the real world beyond the laboratory, ignoring individual differences could prove detrimental not only to performance and well-being but to the fiscal bottom line as well (see Hendrick (1997)). Baldwin's observation also supports the contention that nomothetic models do have a degree of biological reality and that despite the $N = 1$ focus, there may always be a place in design for general principles.

2. Individuals and society

In light of Baldwin's results and observations, one may ask whether customisation is the preferred 'solution' to the 'problem' of individual differences. To address this possibility one has to take an historical perspective on this issue of idiographic variation. To look back now more than 100 years, as the nineteenth turned into the twentieth century, the global population was marginally over 1.5 billion people. Just over 100 years later that number had grown by approximately four-fold. Today there are more than 6 billion persons on planet Earth. It might be anticipated that such an increase, simply in the number of people alive, would see some concomitant reduction in the emphasis on the individual and a comparable rise in the concerns for the collective, even in cultures which intrinsically emphasise individuality (see Hofstede (2001)). However, this has not been the case. Indeed, recent generations have seen an ever greater focus on the individual person (Abelson *et al*. 2008). This trend has been facilitated recently by personal support technologies such as PDAs, portable cell (mobile) phones, etc. Now, a feedback loop is beginning to strengthen between individuality and the subsequent impetus in designing for the individual. Consider for example, a person's 'Facebook' profile. It is evident that people personalise their own page, presenting their specific profile of interests and activities. Alongside this information, any individual can now post their own personal genome on their own personal page (see www.personalgenomes.org). Although we do not at present have sufficient sophistication so as to use this specific genetic information as part of the feedback mechanisms, we do have more macro-level personal expressions of interest. Eventually, we may assume, we will be able to employ individual information down to this genetic level as the currency for feedback regulation. With such capacities, our opportunities to interact and design technologies and experiences for each and every person will be vastly increased and individuation will not merely be the study of each human being but rather the design, expression and regulation of all of their physical and cognitive experiences.

When we come down to it, the central issue in individual differences concerns how we choose to conceive of and treat individuals other than ourselves. This is the case since, in our own personal consideration of ourselves of course, the $n = 1$ rule has always been firmly in place (see Hancock (2005)). Attitude toward others is fundamentally a social issue but the question of considering and exploiting individual differences can also be approached from another direction. We can look at individual differences not in an historic and social way but purely as a problem in computational science. How is it that one can cope with the very large numbers of individual entities who themselves are non-stationary in a number of their characteristics? It is to this scientific and computational perspective that this paper now turns.

3. The nomothetic and the idiographic

As has been previously noted, the traditional way to approach the solution to the large number issue, especially in living systems, is to seek regularities or patterns within the population with which one is dealing. A form of this strategy has been adopted by Matthews and Campbell (2009). As their starting point, they chose to examine sustained performance on a task in which the response capacities of the individual are outpaced by environmental demand. This over-abundance of demand naturally creates a great deal of stress. Matthews and Campbell then use this demand disparity in order to explore the effects of this stress on individuals' coping mechanisms (see Tucker *et al*. (2008)). Matthews and Campbell conclude that personality, as well as individual differences in the dimension of 'engagement', are critical dynamical factors in response. Increased understanding of individual differences is therefore essential to facilitating stress-free interactions between people and their work. There are clear and evident links of this conclusion to Parasuraman's (2009) observations on genetic predisposition and eventually these strategic forms of attack would expectedly coalesce to produce a coherent overall picture. That this picture has to embrace both individuals and groups is evident from the issues involved in evolution, where mutations may themselves be individual but such traits are then inherited across groups where here the analysis must extend across time as well across individuals. That is, intra-individual differences will be as important as inter-individual differences and the issue concerns the level at which one wishes to engage in analysis.

However, the problem of dealing with the commonalities and disparities of groups and individuals is certainly not new. Indeed, in a now classic work of five decades ago, Cronbach (1957) made a number of crucial and trenchant observations about the way psychology, for example, had divided itself into two distinct approaches to the understanding of the human condition (see Cronbach (1975) and Underwood (1975)). The first approach was characterised as correlational psychology, which featured the exploration of observed patterns and relationships in naturalistic settings as the basis for discovering regularities in behaviour. The second, Cronbach contrasted as experimental psychology, which looked to define causal linkages largely by extracting behaviour from its contextual setting. Cronbach argued persuasively for a synthesis of these approaches. However, his appeal for concordance was tempered by a clear understanding of the axis of contention over individual differences. He expressed the experimentalists' concern for individual differences in the following statement:

> Individual differences have been an annoyance rather than a challenge to the experimenter. His goal is to control behavior, and variation within treatments is proof that he has not succeeded. Individual variation is cast into that outer darkness known as 'error variance'.
> (Cronbach 1957, p. 674)

Beyond Cronbach's acidity here, when one considered the stock-in-trade, parametric and non-parametric statistical methodologies of the experimentalist, one can see that the basic distributional assumptions confirm this underlying frustration and angst. Acknowledged or not, the distribution on the x-axis is an admission of incompleteness while the distribution on the y-axis is an admission of ignorance. More specifically, the independent variable of the x-axis (abscissa) exhibits the propensity of the experimentalist to choose one or a highly limited number of variables in which to entertain specific interest. While the outcome variation on the y-axis (ordinate) most often demonstrates that the world is more complex than one might like to admit, since there is almost always unaccounted for variations.

But are individual differences truly a 'problem' to be solved? Cannot one turn this proposition around and suggest that individual differences are actually an opportunity to be exploited? Drury *et al.* (2009) recognise this opportunity and indicate that successful performance in an inspection task, with particular emphasis on inspection in the domain of security, is dependent on manifest and robust individual differences in inspectors. Despite the prominent presence of these individual differences, any attempt to accurately predict the inspection performance of any one inspector remains problematic, if not impossible. In order to assist future research efforts in this area to solve this dilemma, Drury and his associates advocate the creation of a common collection of data, detailing the factors and measures of past experiments. This dataset would purportedly help refine conclusions regarding individual differences in performance and therefore lead to the appointment of more qualified candidates as inspectors. These more efficient and accurate inspectors would indeed prove a useful outcome of such an effort as the modern reality of flying requires the safeguards of vigilant security. Indeed, it is possible to exploit the potential advantages of individual differences in a whole variety of capacities, a recent example being in the dimension of intuition (see Hodgkinson *et al*. (2008)).

For those concerned in human–machine interaction, it is most frequently the case that the basic understanding of the performance of the operator derives from the results of the latter, experimental psychologist. A relevant example of this dependence is the way in which the Goals, Operators, Methods and Selection (GOMS) model uses Fitts' Law as a basis for helping calculate the latency of interaction between a standardised human and a specific operational system (Card *et al*. 1983). The present authors do not decry such a relationship (either in the individual case or in general). Indeed, most advances that this science has made have been founded on these extrapolations. However, the strictures of the limited causal search of the experimentalist have chafed and numerous individuals, as well as whole research groups, have sought ways to circumvent or avoid altogether the limitations that this typical laboratory science brings to real-world prediction. Such concerns were one foundation of the effort to extend the principles of the ecological approach to psychology into human factors (e.g. Flach *et al*. 1995, Hancock *et al*. 1995), as well as the more recent advances in cognitive engineering and the naturalistic exploration of complex systems operations (Vicente 2003, Hollnagel *et al*. 2006). But suppose one did not have to choose between conditional specificity and predictive veracity. Suppose there was a way in which one could use the ascending power of computational systems to circumvent this invidious trade-off. The present authors believe there is and also believe that the answer can be found in a re-evaluation of what was conceived as the original purpose for such research in the first place.

4. Graphing and expressing individual differences

There is one final issue that the present authors wish to discuss before summarising the present commentary. This issue is one that may appear to be a mundane one but on reflection it is believed that it is absolutely one. Quite simply, how does one illustrate individual differences that are truly unique to each individual? This means, how does one plot and communicate the findings from studies of true individuation? People are used to seeing Cartesian (*x*–*y*) plots that show mean and variability. Indeed, as one grows in graphical and statistical sophistication, one can use more advanced presentations such as box and whisker plots. But what is the Cartesian representation for one single individual and one single epoch of behaviour? Also, more problematically, is such a representation at all relevant for individualistic studies? In neuroscience, efforts have been seen to address this issue, in that functional Magnetic Resonance Imaging (fMRI) studies and the like use voxel maps of the brain to show activation 'hot spots' and then summary Cartesian plots, which accompany these individual (or averaged) pictures to show nomothetic trends. This sort of progression suggests that pictures and films might be the best form of representation to accompany the story of one individual experience and responses. In this one might well learn from the visual and media arts, who have sought to pioneer innovation and persuasive ways to convey individual stories. There is no immediate solution to this issue of idiographic results representation but it should be noted that until coherent and persuasive ways are developed and refined to communicate these individual results, then the progress toward individuation will continue to be slow and erratic.

5. Summary and conclusions

If the purpose of science is truly not just to study the world but to change it (Bacon 1620), then it begs two obvious questions (see Hancock (2009)). First, how can change be effected (i.e. what is the process)? Second, what change is to be effected (i.e. what is the purpose)? One obvious way to create purposeful change is to seek to predict, ever more precisely, what will happen in the immediate future. In regard to predicting human behaviour it might well be said that the last century of the second millennia was the era of the nomothetic. The vast majority of the effort expended by experimentalists was focused on the search for general laws of behaviour (see Chapanis (1988)). These efforts sought to take advantage of the regularities discovered to develop and design new technologies. This strategy has led to undeniable progress and, most certainly, these empirical and synthetic efforts will continue to be productive into the foreseeable future. However, to take the next qualitative step of progress one needs to make much more explicit the goals and intentions for predictive knowledge. There remains the laudable search for knowledge for its own sake of course, but eventually knowing and becoming coalesce into the process of predicting. One wants to predict the future so that one can control the future.

Although nomothetic statements, couched in the language of probability, have been the stock-in-trade of the behavioural scientist, it must now be asked whether this is the only, or indeed, the preferred method of future progress. The present authors believe that the world is now in a state of metamorphosis in which one needs to capture all the individuality and subtle nuances of person-specific interaction. It is a supportable statement that there is now the computational power to pursue such a strategy. Indeed, one will have to think well beyond one's traditional conceptions of the person themselves as they can exhibit vast changes in capacity over a lifetime and also show great variation within themselves over shorter epochs and intervals of time. Thus, the focus is not just on inter-individual differences but is just as much directed to intra-individual differences.

If the search for an improved focus on the individual is to go anywhere, one must face the question as to what is the appropriate 'unit of analysis'. In the past, this was clearly man and machine and their respective interaction (Licklider 1960). Obviously, as has been repeatedly pointed out, man–machine interaction must also include woman–machine interaction and, most recently, child–machine interaction (Lueder and Rice 2007). But is it enough now to simply extend this to individual person–machine interaction? Is that the sum total of progress? One alternative perspective is that the appropriate unit of analysis is the use to which the human–machine system is put. That is, not the person by themselves or the machine by itself but rather the use itself (Flach and Dominguez 1995). However, this logic can be extended to redefine the unit of analysis so that it is each specific event as the unit of interaction. At this juncture, one is much closer to story telling than traditional science as it is known (Casey 2006). Yet there are ways to extract regularities and even generalities from individual case events. As the tumblers of the world revolve, it is the inevitable capacity for human beings to perceive these regularities that will encourage progress. If these higher level perceptions bring us back to some formalised logic of enquiry beyond unalloyed statements in probability then, indeed, progress will have been made.

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