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Gibson's ecological approach
– a model for the benefits of a theory driven psychology

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Abstract

Unlike most other sciences, psychology has no true core theory to guide a coherent research programme. It does have James J Gibson's ecological approach to visual perception, however, which we suggest should serve as an example of the benefits a good theory brings to psychological research. Here we focus on an example of how the ecological approach has served as a *guide to discovery*, shaping and constraining a recent hypothesis about how humans perform coordinated rhythmic movements (Bingham 2004a, b). Early experiments on this task were framed in a dynamic pattern approach. This phenomenological, behavioural framework (e.g. Jeka & Kelso 1989) classifies the behaviour of complex action systems in terms of the key order parameters, and describes the dynamical stability of the system as it responds to perturbations. Dynamical systems, however, while a valuable toolkit, is not a theory of behaviour, and this style of research is unable to successfully predict data it is not explicitly designed to fit. More recent work by Bingham & colleagues has used dynamical systems to formalise hypotheses derived from Gibson's ecological approach to perception and action, with a particular emphasis on perceptual information. The resulting model (Bingham 2001, 2004a, b; Snapp-Childs et al. 2011) has had great success with both the phenomena it was designed to explain as well as a wide range of empirical results from a version of the task it is not specifically designed to explain (specifically, learning a novel coordination). This model and the research programme that produced it stand as an example of the value of theory driven research, and we use it to illustrate the contemporary importance the ecological approach has for psychology.

Keywords: Gibson; Bingham; ecological psychology; theory; coordinated rhythmic movement.

When particle physicists recently found that some neutrinos had apparently travelled faster than light (Adams et al. 2011) it never actually occurred to them that this is what had happened. On the basis of the extraordinarily well supported theory of relativity, the physics community went 'that's weird - I wonder what we did wrong?', and proceeded to use that theory to generate hypotheses they could then test. It would take a lot of fast neutrinos to disprove relativity, and even though the result turned out to be caused by a faulty cable, the robust response by physicists stands as an example of the benefits of a good theory.

Similarly, the core of modern biology is the theory of evolution. When creationists say 'we can't see how a bacterial flagellum which rotates like an outboard motor could possibly have evolved, it's irreducibly complex' (e.g. Dembski 2002), biologists are entitled to say 'we have evidence that lots and lots of other things have evolved. Let's see if we can figure out how the flagellum did it, and in the meantime, we're going to operate on the assumption that it did evolve until we have strong evidence to the contrary'. The resulting theory driven empirical work then happily led to a coherent evolutionary story for the flagellum (e.g. Musgrave 2004).

Psychology has many individual theories describing isolated phenomena but no core theory of behaviour to guide our research, no analogue to the theories of relativity or evolution. This is beginning to cost the discipline. Recently Bem (2011) published a series of experiments purporting to demonstrate evidence of precognition. Bem took several standard psychological experiments and reversed the temporal ordering of the elements. Analyses showed a series of statistically significant effects that suggested that events in the near future were affecting earlier performance. For example, he showed participants a list of words then tested their free recall. After this test, he trained the participants on a subset of the words, and showed that there was improved recall of those words, even though the training had come last. Because he followed the rules of experimental design and had statistically significant results, the Journal of Personality & Social Psychology was unable to find a reason to reject the paper. The editors only noted that "the reported findings conflict with *our own beliefs* about causality and that we find them extremely puzzling" (Judd & Gawronski 2011: 406, emphasis ours). Note that the cited conflict was with their *beliefs* about causality, and not, for example, the laws of physics and what they have to say about time travel. This should have been an opportunity for Bem to discuss problems with the standard methods and analyses that produced these physically impossible results (the approach taken in a companion paper by Wagenmakers, Wetzels, Borsboom & van der Maas 2011). Instead, his discussion was framed in terms of a loose reading of quantum physics and an appeal to psychologists to keep an open mind. The paper simply *described* what had happened, without any real attempt to *explain how* it had happened. A failure to replicate Bem's key effects has recently been published (Ritchie, Wiseman & French 2012), but this paper was also entirely empirical and descriptive in nature, with no reference to any underlying theory of how the world works.

Psychology needs a core theory in order to mature as a science. Theory serves a dual role in science. It allows the scientist to identify when a result is likely to be anomaly (e.g. faster-than-light neutrinos), and, more critically, it provides a *guide to discovery* to structure the search for explanations of novel phenomena (e.g. the bacterial flagellum). The Bem experiments demonstrate how, without a theory, psychology is unable to deal rigorously with anomalous results. This paper will discuss how an example psychological theory (James J. Gibson's *ecological approach to visual perception*; Gibson 1966; 1979) has been able to guide discovery and explanation of new phenomena, specifically how people learn to produce a novel coordinated rhythmic movement. It has been able to do this because it is a theory of both the objects of perception and the ecological information that supports that perception. The theory can therefore be used to propose specific mechanisms to *explain* a given behaviour, rather than simply providing some terms to *describe* that behaviour. We will suggest that the successes of this approach in the area of perceptually guided action stands as a clear model of what a truly theory-driven psychology could achieve.

The ecological approach – a brief review of some key points

Gibson famously begins his 1979 book on visual perception with an extended analysis of the environment organisms inhabit, rather than the more traditional starting point of the anatomy of the eye. The reason is simple: Gibson knows that in order to understand why the anatomy of the eye is the way it is, we need to first understand what kinds of properties it has evolved to detect. The traditional analyses note that the eye works similarly to a camera, with a lens that focuses light (presumably an image) upside down onto a pixelated retina that varies wildly in resolution and which contains an enormous blind spot. The analysis then takes this poor quality image as the basis of visual perception and begins to investigate the internal (representational) structures that are now required to enrich the image to a point where it can support the rich phenomenology of visual experience (e.g. Marr 1982; Rock 1985). Gibson's first powerful move is simply to recognise that the eye is not the starting point of the analysis. Eyes evolved under selective pressure to enable access to information in the environment that could support action and guide behaviour. The question then becomes, what is that information, and what is it about?

This move pays off immediately. If the function of vision is to support action, then vision must provide us with access to information about action relevant properties of the world. Organisms don't need to know how far away an object is; instead, we need to know whether we can reach it, and if so can we grasp it (e.g. Mon-Williams & Bingham 2011); or perhaps we need to know whether it is approaching us on an interception path, and if so do we have enough time to respond by evading or intercepting the object (e.g. Tresilian 1999). We therefore need to know about properties of objects measured according to our ability to act with respect to those properties, and how the current layout of properties is varying over time. Gibson coined the term *affordances* to describe the organism-scaled action relevant properties of the environment,[24] and changes in the layout of the organism's environment are *ecological events*.

[24] There is something of a debate in the literature about whether affordances are dispositional properties of the environment (Turvey 1992; Turvey, Shaw, Reed & Mace 1981) or whether they are relational properties of the animal-environment system (Chemero 2003, 2009; Stoffregan 2000, 2003). We favour the dispositional

Defining these ecological properties of the world is relatively straight-forward: Gibson then notes that ''The central question for the theory of affordances is not whether they exist and are real, but whether information is available in the ambient light for perceiving them'' (Gibson 1979: 140). Gibson's theory therefore suggests that the prime goal of any empirical investigation should be identifying the perceptual information that supports access to world properties (affordances and events) and his analysis of the nature of the information available to a visually perceiving organism, *ecological optics*, provides clear guidelines on what that information can look like[25].

Gibson's analysis of the environment identifies two key facts. First, the basis for vision is not light, per se, but structure in light. The clearest demonstration of this is the Ganzfeld experiments, in which an observer is presented with plenty of light in an entirely homogeneous light field and perceives nothing at all (Gibson & Dibble, 1952; Metzger, 1930). This is the situation faced by an observer in white-out conditions during a blizzard; there is plenty of light energy, but there is no structure, and thus nothing is perceived, often with disastrous consequences. However, light that has interacted with a surface contains structure that reflects (pun intended) that interaction and can therefore carry information about the surface. Gibson calls this structured light the *optic array* and identifying the contents of this array is the main focus of ecological psychology research.

Second, organisms are always moving throughout the environment. This motion provides us with a constantly changing sample of the optic array, and, more importantly, the changes are not random. Instead, the structure in the array will transform smoothly and in ways specific to the relation between the organism and the ecological properties of the world that caused the structure. Higher order relational structure in this *optic flow*, which is caused by these world properties, can remain *invariant over the transformation*, and these invariants are specific to the properties that caused them. These invariant features are therefore specifying information about affordances and events, and an organism that can detect the information is directly perceiving ecologically relevant properties of the world (Bingham 1995; Turvey, Shaw, Reed & Mace 1981).

The ecological approach serves contemporary psychology and cognitive science in two ways. First, while Gibson's theory is not a complete theory of behaviour, it is an excellent foundation for one, because it provides a detailed account of how we perceive the environment that changes how we treat perception. Direct perception of affordance properties changes the job description for any cognitive, post-perceptual processes, from inference about the source of the information to using that information to coordinate and control skilled action. If you have direct access to action relevant proper-

account, but the difference is not crucial for the current discussion; in both cases affordances are considered to be real and capable of creating information.

[25] Ecological optics has since been refined into the theory of *kinematic specification of dynamics* (e.g. Runeson & Frykholm 1983). Properties of the world are defined dynamically, in terms of both their motions (kinematics) and the forces that caused those motions (kinetics). Perception has access only to kinematic information (this is the *perceptual bottleneck*; Bingham 1988) but this is capable of specifying dynamical properties.

ties such as affordances, for example, there is no need for any internal process that infers the existence of the affordance from a more limited set of perceptual information. In other words, any theory about behaviours that depend on perception (i.e. all of them) should work out what Gibsonian perception has already done to allow the behaviour to emerge before placing all the responsibility in the central nervous system. In this way, the ecological approach should be treated as the starting point for *any* theory of behaviour. In particular, embodied cognition researchers are beginning to realise that if cognition is a system which spans body, brain and environment (e.g. Clark 2008) we need a way for information to flow through this system in order to softly assemble (temporarily couple) the task relevant components. The ecological approach has many of the relevant tools already in place (specifically, methods for identifying the relevant perceptual information and how action systems use this information to coordinate functional responses to a given task; Bingham 1988) and is therefore already ideally placed to support extended, embodied cognition (Barrett 2011). Chemero (2009) has comprehensively covered what a cognitive science grounded in the ecological approach would look like in his recent book. Some minor quibbles aside, we endorse his view and so won't rehash it here.

The second contribution of Gibson's theory (and the focus of this article) is how it stands as an example of what a theory driven research programme in psychology looks like and is capable of. Specifically, the theory serves as a *guide to discovery*, capable of driving forward an empirical research programme by asking the right questions and constraining what counts as a legitimate answer. Instead of simply summarising and describing what happened in an experiment (as is common throughout cognitive psychology), the ecological approach postulates a theory about the nature of perceptual information and what it means that enables researchers to explain their results and make novel predictions that go beyond the current data. In the next section, we will review a recent programme of empirical work on the identity of the information specifying the relative phase between two coordinated rhythmic movements. This work, led by Geoff Bingham in concert with a variety of collaborators, has culminated in a perception-action model of the task in which, for the first time, a specific hypothesis about information features prominently (Bingham 2001, 2004a, b; Snapp-Childs, Wilson & Bingham 2011). The model, and the strategy for assembling it stands as an exemplar of how the ecological approach can *guide* research and it clearly demonstrates the benefits of a theory driven approach to psychology. We will contrast this approach with the phenomenological (descriptive) *dynamic pattern* approach (Kelso 1995; Zanone & Kelso 1994) which focused on simply describing key experimental results and remains unable to make successful predictions about novel experimental procedures.

Perception, action and coordinated rhythmic movement

Coordinated rhythmic movement has been a staple of the perception-action literature since the basic task characteristics were described by Kelso (1981; see Kelso 1995 for a detailed overview). The core task is simple: take your two index fingers and move them up and down so that they do the same thing at the same time; this is 0° *mean relative phase* and is easy to produce and maintain over a wide range of frequencies. Now make your fingers alternate; this is 180° mean relative phase, and is also easy to produce and maintain, though over a smaller range of frequencies; at 3-4Hz, under a 'non-interference' instruction, 180° becomes unstable and people typically transition into 0°. Other coordinations (especially the intermediate 90° rhythm) are typically unstable without training and people cannot maintain them in the face of perturbations such as an increase in frequency.

These phenomena were described by the famous Haken-Kelso-Bunz model (Haken, Kelso & Bunz 1985). The model implements a *dynamic pattern* approach to coordination phenomena. It models an abstract dynamical process rather than the task of coordinating two limbs in particular, and the form of the model (two superimposed cosine functions) therefore makes no particular reference to anything about coordination other than being organised with respect to relative phase. Specifically, the two cosine functions describe an energy potential function; this function has local minima at 0° and 180°, with the minimum at 180° being shallower and wider. These minima represent *attractors*, locations within the model's state space that draw behaviour towards themselves, while 90° is represented as an energy maximum, i.e. the energy required to maintain the state is maximal and thus it is unstable. This basic form of the model describes the *intrinsic* dynamics of the system, the preferred state. These dynamics can be altered, however, with learning. In the dynamic pattern approach, learning is described as a phase transition, in which an imposed environmental rhythm (e.g. 90°) is incorporated into the intrinsic dynamics as a third attractor (e.g. Schöner & Kelso 1988; Zanone & Kelso 1992, 1997). This happens after a period of competition for dynamical resources between the intrinsic and imposed attractors, and the phase transition is the resolution of this competition via a reorganisation of the system as a whole.

The research strategy advocated by Kelso is behavioural and dynamical (e.g. Jeka & Kelso 1989). Researchers should identify the *order parameters* of a system along which behaviour is organised (here, relative phase) and determine the nature of the dynamics by investigating the stability of the system in response to perturbations such as frequency scaling and the imposition of a to-be-learned rhythm. Experiments taking this approach have identified critical stability fluctuations as frequency increases, fluctuations which abruptly decrease after a phase transition from, say, 180° to 0°, as well has phase resetting and an inverse frequency-amplitude relation (Kay, Kelso, Saltzman & Schöner 1987; Kay, Saltzman & Kelso 1991).

Overall these results suggest that coordinated rhythmic movements are an example of an autonomous non-linear dynamical system. However, the HKB model and this modelling strategy are entirely phenomenological: the equation is abstract and designed solely to fit the basic pattern of the data. There is no account of the *origin* of the attractors; if behaviour is organised with respect to relative phase, why are 0° and 180° so easy? Why is 90° maximally difficult? In effect, Kelso's approach provides a clear understanding of *how* rhythmic movement is organised in people, but has no account of *why* it should be this way. This weakness revealed itself when the approach was applied to a phenomenon it wasn't specifically designed to explain: trained performance at relative phases other than 90°.

Learning (the dynamic pattern approach)

The dynamic pattern approach considers learning to be a process of competition over limited dynamical resources between the intrinsic task dynamics (the HKB model) and extrinsic task demands (an externally paced rhythm). Zanone and Kelso (1994) laid out several predictions about how this competition should unfold when learning various novel coordinations. Learning something close to 0° (e.g. 45°) would be more difficult than learning something an equal distance from 180° (e.g. 135°) because the attractor at 0° would exert a stronger pull on this unstable state and prevent people from being able to maintain it.

This has been tested twice, by Fontaine, Lee & Swinnen (1997) and Wenderoth, Bock & Krohn (2002). Both studies trained participants to perform novel coordinated rhythmic movements that varied in their distance from the two intrinsically stable states (e.g. 36°, 45° 60°). Contrary to the prediction, learning a novel coordination close to 0° was easier (faster and more stable) than learning one close to 180°. Competition from pre-existing attractors does not explain this, but Wenderoth et al suggested that some earlier work from Bingham's lab (Zaal, Bingham & Schmidt, 2000) on the visual perception of relative phase contained the answer. 0° is not stable because there is an attractor there; rather, 0° can be described as having an attractor there because it is stable, and that stability is a function of how relative phase is visually perceived. Information, not dynamics, held out the possibility of an explanation.

The perceptual basis of coordinated rhythmic movements

Schmidt, Carello & Turvey (1990) demonstrated that the HKB phenomena are still present when the limbs being coordinated belong to different people and the coupling is visual. Bingham then ran a series of visual judgment experiments, in which he asked participants to visually evaluate displays of dots moving at some mean relative phase with varying frequency and amounts of variability in the coordination (Bingham, Schmidt & Zaal 1999; Bingham, Zaal, Schull & Collins 2001; Zaal, Bingham & Schmidt 2000). The results were quite startling. Participants could do the task on average but the variability of their judgments varied in the HKB pattern (low variability at 0°, maximum variability at 90° and intermediate variability at 180°). Thus, 0° was judged to be maximally stable, 180° stable but less so, and 90° maximally unstable even with no added noise; when phase variability was explicitly added, this was only clearly discriminated at 0°, somewhat at 180°, and not at all at 90°. Bingham had shown that the HKB pattern from the *movement* task also showed up in a purely *perceptual* task, suggesting that the pattern in the movement task was being caused by how relative phase is perceived. Wilson, Bingham & Craig (2003) then replicated this result using haptic perception of relative phase.

Following on from this, Wilson, Collins & Bingham (2005a) had people move at 0°, 90° or 180° in order to produce 0°, 90° or 180°, in varying combinations. In the conditions where the mapping was not altered (e.g. moving at 0° to see 0°, or at 90° to see 90°) we saw the HKB pattern. In the transformed mapping conditions, however, movement stability followed the visual feedback. Movements at 90° and 180° were both stabilised if the display showed 0°, while movements at 0° were made less stable if the display showed 90° or 180°. The stability of coordinated rhythmic movements followed the perception of relative phase, and not the relative phase of the movement per se (see also Bogaerts, Buekers, Zaal & Swinnen 2003).

Relative phase is clearly perceivable. The question is how; what is the information for relative phase? There were hints in the literature that relative phase was perceived in terms of the *relative direction of motion*. Relative direction perfectly predicts the movement phenomena; it is maximally stable at 0°, stable but less so at 180° and maximally variable at 90°. In addition, the HKB pattern goes away when relative direction is not defined (e.g. orthogonal movements: Wilson, Collins & Bingham 2005b; Wimmers, Beek & van Wieringen 1992; transformed (Lissajous) feedback: Kovacs, Buchanan & Shea 2009a, b). Gibson made sure to emphasise, however, that it is *always* an empirical question which information people use. Wilson and Bingham (2008) systematically and selectively perturbed all the components of motion that could conceivably specify relative phase (relative speed, relative frequency and relative position). None of the perturbations had any effect other than to add a small amount of noise to judgments of 0° and 180°. In addition, it proved impossible to perturb relative direction without making the relative phase undefined. We therefore concluded that relative phase is perceived in terms of the relative direction of motion.

A perception-action model of coordinated rhythmic movement

Bingham had now established that the movement phenomena reflect the perception of relative phase. However, remember that skilled actions are perception-action systems – perception is not the entire game (as erroneously claimed by Mechsner, Kerzel, Knoblich & Prinz 2001). Bingham therefore needed to model the full perception-action task in a manner that accurately reflected the actual *composition* and *organisation* of the task dynamic. Bingham's intention was that this model should reflect the ecological approach that had guided the discovery of the identity of the task elements. The model could not simply contain parameters designed to fit the data; everything in the model should represent an empirically identified element of the task dynamic of coordinated rhythmic movement.

The first step was a *task analysis* to identify the dynamical resources that were available to be softly assembled into a task-specific device that produces the observed behaviour (Bingham 1988). This analysis revealed that we need to model two rhythmically moving limbs which are coupled together via perceived relative phase. Rhythmically moving limbs exhibit very specific properties; they show *limit cycle stability* (their preferred state is periodic), *phase resetting* (they respond to perturbations such as being sped up or slowed down by returning to the limit cycle at a different phase than if they had remained unperturbed), an *inverse frequency/amplitude relation* (as frequency increases amplitude goes down unless instructed otherwise) and a *direct frequency/velocity relation* (Kay, Kelso, Saltzman & Schöner 1987; Kay, Saltzman & Kelso 1991). These characteristics mean that the control of the limbs is non-linear and autonomous (i.e. they are driven as a function of their own behaviour, not of time). Bingham therefore modelled the limbs to-be-coupled as damped mass-springs (following the equilibrium point hypothesis, e.g. Feldman, Adamovich, Ostry, & Flanagan 1990).

Perception enters the model in the coupling function. Each mass-spring is driven by the perceived phase of the other limb, modified by the perception of relative phase (in terms of relative direction) and with noise proportional to the relative speed (Wilson et al. 2005b; Snapp-Childs et al. 2011). Relative direction and relative speed are both state variables and thus can be used to drive a mass-spring autonomously; they are also both kinematic and thus perceivable (Bingham 1988; Runeson & Frykholm 1983; Turvey et al. 1981). The final form of the model (Bingham 2001, 2004a, b) is therefore

$$\ddot{x}_1 + b\dot{x}_1 + kx_1 = c\sin(\Phi_2)P_{12}$$

$$\ddot{x}_2 + b\dot{x}_2 + kx_2 = c\sin(\Phi_{1)}P_{21}$$

where $P_{ij} = sgn(\sin(\Phi_i)\sin(\Phi_j)\big) + \alpha(x_i - x_j)^3 N_{t)}$

This model is the first fully perception/action model of coordinated rhythmic movement. It explicitly models both perceptual and action components as having specific forms, and it places these components in a specific organisation with respect to each other. It also makes three specific predictions, all empirically confirmed; that the information for relative phase is relative direction (Wilson & Bingham 2008), that the movement phenomena are a function of perceptual stability (Wilson, Snapp-Childs & Bingham 2010) and that relative speed acts as a noise term (Snapp-Childs et al. 2011).

The model as guide to future discovery – learning (the ecological approach)

Like the HKB (and any decent cognitive model) Bingham's model is very successful in explaining the things it is designed to explain. However, it has an extra dimension that the HKB lacks. Specifically, it is the product of a theory-driven process which uniquely demands that the model be built from components that have been empirically determined to matter, and that these components must be built so as to reflect the real composition and organisation of the system at hand. The model does not yet explicitly handle trained performance at, say, 90°; however, recent learning research inspired and guided by the ecological theory the model embodies has met with great success.

The model assumes that movement stability is a function of perceptual ability. This suggests that if people became expert perceivers of 90°, they should then be able to move at 90° with no practice at the task. This is indeed the case (Wilson et al. 2010a).

The model also suggests that learning 90° is unlikely to involve simply improving your ability to detect relative direction at 90°; this variable remains intrinsically variable at 90° and thus cannot support stable action there. The model therefore suggests that people trained at 90° are likely to switch to a new variable; Experiment 2 of Wilson & Bingham (2008) perturbed the performance of the trained observers and found that they had switched to perceiving relative phase as relative position (but only at 90°). Finally, as noted above, Wenderoth et al. (2002) explained their learning rate data in terms of Bingham's perception hypothesis; if the region around 0° is clearly perceived then different states there can be clearly discriminated and learning these states is therefore easier than around 180°.

The model also predicts that there should be transfer of learning between bimanual and unimanual versions of the task because while the coupling in the unimanual case is only in one direction, it is still composed of relative motion information (Snapp-Childs et al. 2011). This is indeed the case; there is transfer, and the form of the transfer matches the predicted stability characteristics of the unimanual and bimanual versions of the task (Snapp-Childs, Wilson & Bingham, submitted). This is quite remarkable; predicting how learning will transfer is a notoriously difficult problem in motor control (Schmidt & Young 1987). The ecological approach the model embodies, with its emphasis on information, makes clear and so far successful predictions about a task it is not explicitly set up to handle because it can base these predictions on a hypothesis about the underlying mechanism.

Summary

Sciences need theories, to guide discovery and constrain explanation. Gibson's ecological approach has shown itself capable of supporting productive and successful empirical research across a wide range of tasks and serves as a model for what a theory-driven psychology could achieve. Reviews of other work in this vein can be found in Barrett (2011) and Chemero (2009). We have focused here on Bingham's perception-action model as an exemplar of this research and how the ecological theory underpinning the model successfully guided discovery and ruled out alternative explanations for phenomena. In addition, while the ecological approach is not a complete theory of behaviour, it is a successful theory of perception, and this must therefore be the starting point of *any* analysis of behaviour. By beginning that analysis at the right place (in the opportunities for behaviour in the environment and the information about those opportunities) the ecological approach will inform, enrich and (most importantly) constrain our explanations of behaviour in a principled manner (Chemero 2009).

Gibson's ecological approach therefore continues to have much to offer contemporary psychology, but it remains to be seen if psychologists can accept and work within the constraints of a real theory as they attempt to explain more complex cognition and behaviour. The beauty of such a period of theoretically motivated, hypothesis driven 'normal' psychological science is that if we invest some serious time pushing the theory, looking for cracks, and resisting the temptation to jump ship at the first sign of trouble, psychology will end up in a better place no matter how it pans out. If the theory breaks, it will have been broken honestly, and for good reasons. If the theory holds up, we will have achieved a lot of progress and begun to act like a real science for a change. Either way, psychology will be a stronger science for the experience.

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