Critical Ratios as Behavioural Indices of Presence

Abstract contribution for 2nd international workshop on presence

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Summary of main contributions (Bullet points):

- Definition of presence; relation between behaviour and experience.
- Embedding of these two concepts in the theory of body-scaled affordances (J.J. Gibson's 'ecological approach').
- A measurement indicator based on regime transitions (nonlinear dynamics).
- Discussion of this indicator in comparing behaviour in natural-world and VR conditions.
- Implications for designing VR experiences.

Main document of the work to be presented (4 pages---without pictures, that is)

Critical Ratios as Behavioural Indices of Presence

Direct experience of a natural ecology

A father and his five-year-old son stand on the beach watching the surf pound the shore. They see the same ocean, the same waves, but are they having the same experience? The same physical event is experienced and responded to in a different way. For the five-year-old the waves are huge and frightening, breaking over his head with a force that could easily knock him down. For the father the waves are not nearly as dangerous or threatening. The son would have to run away, the father could quickly stand up. While the waves are physically the same, they are clearly not functionally the same for these two observers. While the father and son are in the same environment, they are in different ecologies. That is, the significance of a wave is relative to the size of the observer. A wave that is "big" for the son is not so big for the father.

Do the differences in the experience of the waves reflect purely subjective interpretations of the environment or is there an objective physical basis for this difference? This is one of the challenges of an ecological approach to human performance --- *to provide an objective description of ecologies that can explain the different direct experiences of different observers*. One strategy that has been adopted in an attempt to provide this objective basis is the use of dimensionless 'Pi' numbers to characterizes objects in an ecology. For example, the size of the waves might be measured in relation to the eye-height of the observer. A wave that is twice the eye-height of the five-year-old is less than half the eye-height of the father. Thus, the "bigness" of the wave experienced by the five-year-old might be several magnitudes larger than that experienced by the adult. The dimensionless ratio (wave height/observer height) provides a common scale were bigness may be characterized relative to different observers. A two eye-height wave is big! A one-half eye-height wave is small.

The father and son walk down the beach and encounter a brink as illustrated in Figure 1. What is the best way to manage this brink? Can they simply step over the brink using a normal gait? Or does the brink require a change in action mode? Does the brink require a jump or a climb mode of action? Again, the relative nature of the ecology is evident. A brink that the father can step over with little change in gait may require a major gait adjustment for the five-year-old. Thus, the same quarter meter brink may be experienced and responded to very differently by the two observers. Again, however, dimensionless Pi numbers might help to account for the differences. Here eye-height or leg-length might be the appropriate value for the denominator of our dimensionless ratio. Research has shown that relative action boundaries reflecting reaching, grasping, passing through, stepping-up, stepping-over, sitting-on, etc. can be characterized using critical values on these dimensionless Pi scales. Observers of various sizes make action transitions at the same critical values. Moreover, experiments have shown that people are perceptually sensitive to optical variables expressing these Pi scales (e.g., eyeheight-scaled aperture widths).

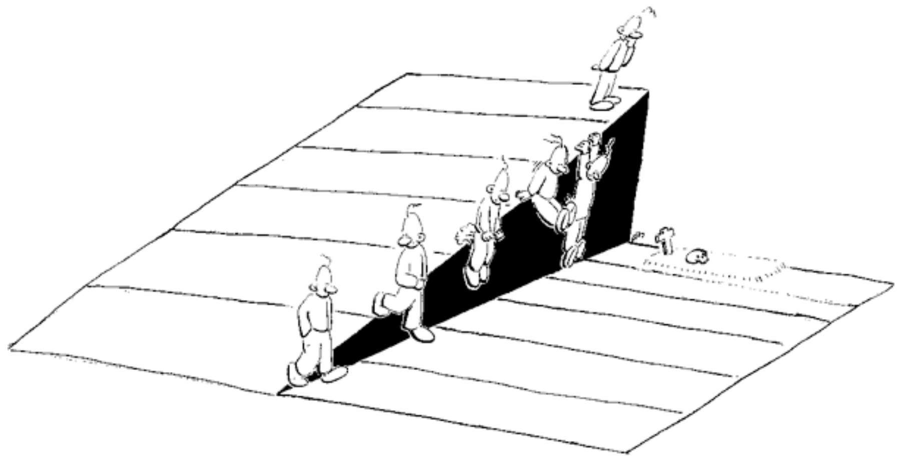

Figure 1. A continuous range of heights breaks up in discrete ranges of perceptual meaning (mode of descent), marked by body-scaled ratios.

These two examples illustrate one of the strategies that an ecological psychology has adopted in order to account for the direct experiences of actors in natural ecologies. Can this same strategy be applied to the study of presence in virtual ecologies?

Presence in a virtual ecology

Presence refers to how the objects in a virtual ecology are experienced by the actor/observer. Are they experienced as abstract computer images (low or weak presence) or are they experienced as concrete physical objects (high or strong presence)? How do the experiences in the virtual ecology compare with the experience in the natural ecology that is being simulated? Is a wave that is large and threatening in the natural ecology, experienced as large and threatening in the virtual ecology? How does performance in the virtual ecology compare to performance in the natural ecology? Does a brink that elicits a gait adjustment in the natural ecology elicit a similar response in the virtual ecology? If the experiences and responses in the natural and virtual ecologies are very similar, then presence is said to be high (strong); if the experiences and responses are different, then presence is low (weak).

Subjective experiences are often used to measure presence. However, a problem with such measures is that the subjective experiences and behavioural responses are sometimes in conflict. For example, Brooks relates the incident where a critical user complained that the table he was viewing throught the HMD looked nice, but not real. The user then stumbled when he attempted to get up from a kneeling position by resting his hand on the virtural table for support. The subjects subjective report suggests that presence was low, but the behavioural error of leaning on a virtual table suggests that presence was high.

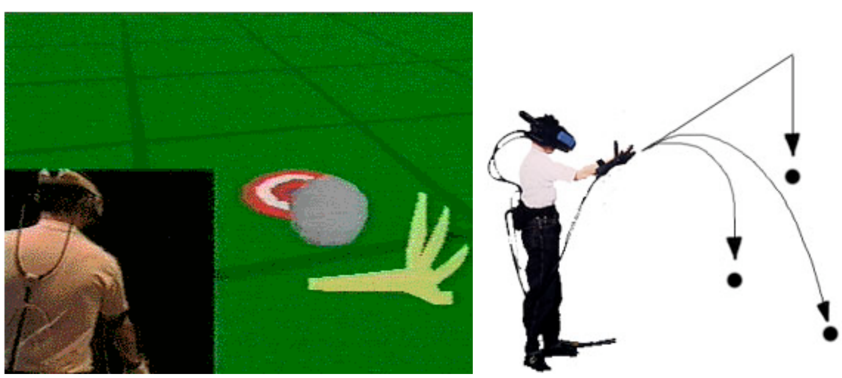

Figure 2. Experiment throwing balls at targets in VR (left). The dynamics of the ball could be changed between Newtonian, Aristotelian, and Medieval motion theories, implementing different, but similar paths (right).

Also, the sense of presence does not always improve with increased correspondence between the objective physical properties of the real and virtual ecologies. For example, in one experiment subjects threw balls at targets, but the physics of the balls was different from the physics in the natural ecology: instead of gravitational force of g = 9.8 m/sec/sec, gravity was higher or lower; also, the balls could fly either in Newtonian parabolas or according to ancient models composed of circles and straight lines. A surprising finding here was that people can competently hit the targets with each of these types of physics, and none was experienced as strange, as long as the basic principles of throwing were similar (e.g. , throwing the ball harder gets it a further distance). Moreover, when people could throw balls which moved according to Newton's laws, and were asked to adjust the value of gravity used in the simulation to its natural value, they would end up setting it to approximately half its natural value (5 m/sec/sec). This might be explained as due to the delays involved in the simulation, but the important thing here is to see that at the lowered value of gravity, the actions were competent and the situation was judged as 'like real life', whereas at the 'real' setting of gravity, performance was low and experience was 'too fast'.

In another experiment subjects were asked to walk through a narrow openning between two poles without hitting them with their shoulders, as illustrated in Figure 3. The independent variable was the size of the gap between the poles and the dependent variable was the degree of shoulder rotation as the observer passed through the poles. Performance was first measured under natural direct viewing conditions in a natural environment (in conditions with and without the VR peripherals, named 'Free' and 'Mock-up', respectively). As shown in Figure 4, in the natural ecology there was a clear inflexion point, indicating a critical value of about 1.5 shoulder widths. That is, when the gap was greater than 1.5 shoulder widths there was no shoulder rotation. Below 1.5 shoulder widths, the amount of rotation was inversly related to the gap width. When performance was measured under virtual display conditions the critical point became far less evident. Shoulder rotation was inversely proportional to gap size across the full range of widths. The slope of this curve was much flatter than the curves in the natural viewing condition. The 'variability bump' marking the critical ratio in real-light conditions was greatly reduced in mock-up conditions, disappeared in the VR condition.

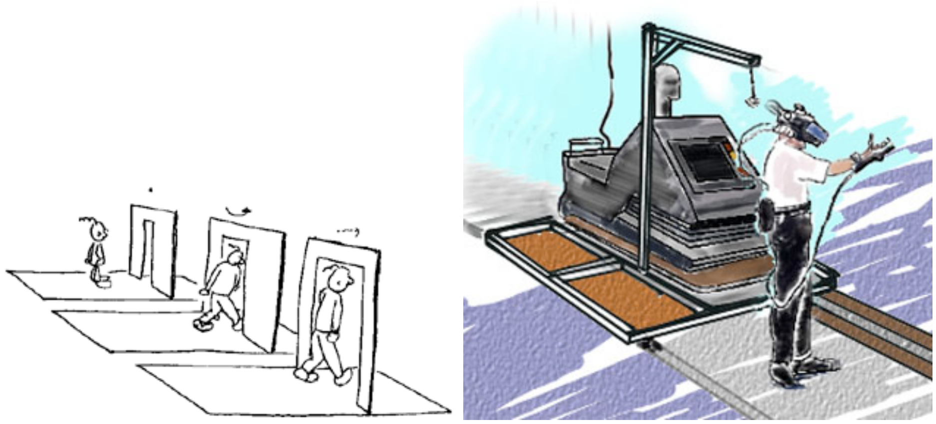

Figure 3. Experimental task: walking through an aperature. For narrow gaps, people will rotate their torsos to avoid hitting the sides. This torso rotation can be seen as a measure of the 'experienced width' of the aperture. Right: sketch of the VR setup. The simulator followed the subject over a 16 meter track.

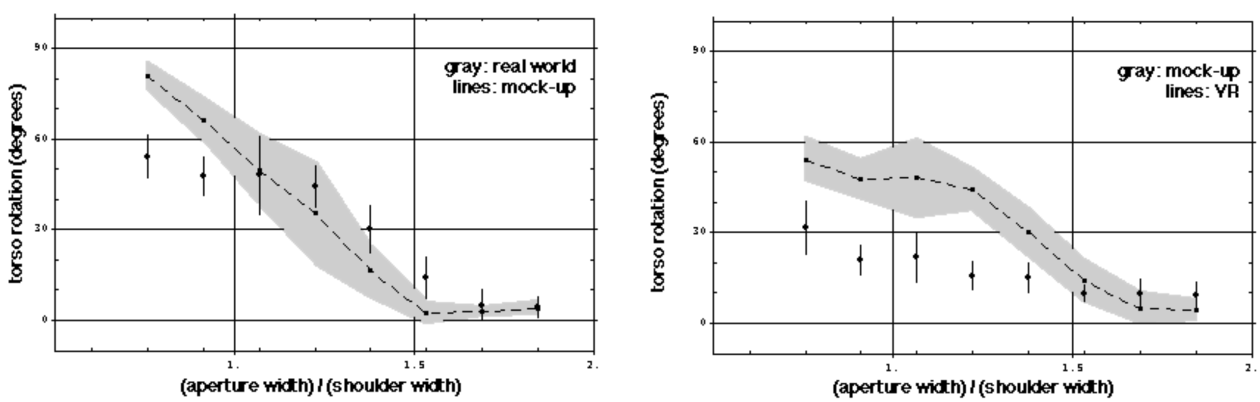

Figure 4. Torso rotation as a function of gap width for subject M-1 in the Free, Mock-up conditions (left) and Mock-up and VR conditions (right). You will see that the Free and Mock-up conditions show a clear discontinuity. The VR condition shows a sloping line with no discontinuity.

Great care was taken to match the perspective and motion parallax for the VR and natural viewing conditions in the experiment above. Yet, the performance curves suggests that the observers did not experience the two ecologies in the same way. In the natural viewing condition, subjects appeared to view the gap size in relation to their own shoulder width. This allowed them to alter their response mode in response to a critical value of 1.5 shoulder widths. In the virtual environment the subjects were sensitive to gap size, but there was no evidence that they could relate that size to their own shoulder width. That is, there was a shoulder rotation for every gap size, even when no rotation was required to pass through the gap.

Implications

The above examples, together with other experiences in virtual ecologies suggests the following implications for presence.

1. Subjective reports alone are unreliable measures of presence. Where possible they should always be supported with performance measures.

2. Presence does not alway reflect the objective similarity of abstract physical laws within the real and virtual environments.

3. Even high fidelity matches between the perspective geometry in the real and virtual environments may be insufficient to create identical experiences.

The last experiment illustrates how the use of critical values from ecological approaches to performance may provide very important behavioural indices for comparing real and natural ecologies. We propose that these critical values may by fundamental to comparing the functional experiences in a virtual ecology to the natural environment that is being simulated. For example, we propose that in training simulators (e.g., for driving, aviation, or surgery) these critical values may be essential for the development and transfer of skill to the natural environments. A skilled driver must see the distance between her and the car that she is following relative to her braking and maneuvering abilities. A safe following distance reflects a critical ratio that relates the speed and distance to the braking capabilities of the vehicle. If the skills developed in the simulartor are to transfer to the natural ecology, then there should be close correspondence between the critical values discovered in the simulator and those in the operational ecology. A speed and distance that is experienced as "safe" in the simulator better be safe in the natural ecology.

Thus, in measuring the fidelity of a simulator, researchers should measure critical values and compare these to critical values in the operational environment. For example, comfortable following distance might be measured as a function of speed in both the real and virtual ecologies. Are there critical points on this performance curve? How do the critical points found in the operational environment compare with critical points found in the virtual environment?

In sum, our experiences of the real ecology and our experiences of a virtual ecology depend in part on our ability to relate the objects in the ecologies to our action capabilities. These relations can be defined through dimensionless ratios. Changes in action modes will be associated with critical values of these dimensionless ratios. In turn, these ratios can be used as guidelines for implementing interactivity in synthetic environments. If a simulator's aim is to make the user experience the world as a child, a giant, or a bird, just lowering or raising the eyeheight is not sufficient: the simulation should realise the relevant action ratios and their critical values of climbability, passability, reaching range, etc. These critical values may provide important indices for comparing the experience in the natural ecology with presence in a virtual ecology. If a simulator's aim is to match experience in the virtual ecology to that in the real ecology, then both ecologies should implement the same values for relevant ratios.