ESSAYS

Multiple Sources of Information: For What?

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Pittenger (1989) raises pithy and pertinent questions with his essay "Multiple sources of information: threat or menace". He offers as "gut level beliefs" the notions 1) that many everyday events are multiply specified, and 2) that multiple specification is consistent with a theory of direct perception. I take issue with both of these claims.

What is Multiple?

Gibson (1966) claimed that fire is multiply specified in volatile, optic, acoustic, and thermal arrays. What does this mean? Are these four sources of information equivalent? Can each substitute for the others? Does each in isolation convey the same information as any combination of them? Are the various specifications independent of one another? More succinctly, are they redundant? Gibson (1966, p. 54) states that they are. Pittenger agrees: "to perceive people's age you can attend to their head shape, the shape of the parts of their face, *or* the height of their head relative to that of the rest of the body" (1989, p. 4, emphasis added). I have appealed to "cross - modal redundancy" myself (Stoffregen & Becklen, 1989).

The Centrality of Intermodal Invariants

I think that the central issue here turns on our understanding of what exactly is specified. Take looming. There is a unique lawful relation between time - to - contact and parameters of optical and acoustic stimulation (Schiff & Oldak, 1990). These parameters of stimulation have been shown to have robust effects on the phenomenal experience of impending collision (Schiff & Oldak, 1990), and, for optics, on behavioral responses to it (Lee & Young, 1986). We are familiar with the mathematical formula relating time - to - contact to the rate of expansion of the image of an object or surface. Discussions of impending collision treat this invariant in isolation. But organisms do not pick up individual sources of stimulation in isolation. I'm willing to wager that they could not, no matter how hard they tried. It is easy for us as scientists to ignore it, but the fact is that each of our perceptual systems is always operating; none of them ever shut down (closing your eyes is a trivial exception). Organisms pick up information through multiple perceptual systems during every waking moment, at a bare minimum for the perception and control of posture and orientation (Stoffregen & Riccio, 1988). It is sometimes assumed – when it is thought about at all – that this consists of the multiple pickup of redundant information. However, the *pattern* of stimulation *across* systems is informative, as Gibson (1966, p. 62-63) pointed out, and as Gary Riccio and I have argued extensively (Riccio & Stoffregen, 1988; Stoffregen & Riccio, 1988). Moreover, we have argued that much information is available *solely* in patterns of stimulation across perceptual systems (also known as intermodal invariants; Gibson, 1966; Stoffregen & Riccio, 1988).

What has this to do with events like fire, or impending collision? Several things. First, it is an error to assume that organisms attend to individual perceptual systems, or to individual sources of information. Gibson was at pains to point out that organisms per-

ceive events, not the activity of perceptual systems. Hence an organism will not perceive "the visual specification of impending collision". Instead, it will perceive "the event of impending collision", however that may be specified.

This is where things get interesting. It is argued or implied that impending collision, fire, and so on are multiply (redundantly) specified in stimulation of different perceptual systems. But what is specified in the total pattern of stimulation across systems? If you see fire, hear fire, smell fire, and feel fire you will perceive fire. But not just any fire; you will perceive fire that can be seen, heard, smelt, and felt; in short, fire right in front of you. What is perceived if you smell fire but do not hear, see, or feel it? Fire, yes, but this percept and the previous one are not *equivalent.* With only smell you perceive fire - out - of - sight - at - a- distance, or fire - out - of - sight - upwind. Other combinations of the four kinds of stimulation would be caused by other combustion events. Would these events be perceived as such? If so, are the different "sources of information" really equivalent? Consider the case of impending collision: imagine yourself tied to a railroad track. Engine 99 approaches. Ordinarily you would see, hear, and feel the approach (through the ground and air). It is likely that time-to-contact is available in each of these forms of stimulation. When all are present and "redundant" you doom is specified. But what is specified, what event, if you see and feel the train but cannot hear anything? What event is specified if you can hear and see the train but there is no rumble in the tracks, no vibration in the air? With these intermodal patterns of stimulation what would you perceive? You might still perceive time - to - contact per se, but that is certainly not all that you would perceive, and your interest in time - to - contact might be substantially altered. In each of these cases the perception of the actual event (rather than some isolated property of the event) is dependent on the pattern of stimulation across perceptual systems. Different patterns of stimulation across perceptual systems are specific – uniquely related – to different events.

It will be objected that there are events that do not stimulate multiple perceptual systems but which seem nevertheless to be perceived veridically. Impending collision remains a good example. A fly ball structures light but it does not structure sound, and it does not structure mechanical stimulation of my body (before it hits me). Unimodal perception? I think not. A fly ball does not structure stimulation of the auditory system, but that system is functioning. If the ball structured the acoustic array the structure, specifying time - to - contact, would be available to the auditory system. The absence of such acoustic structure *combined* with the presence of optical structure (that is, the pattern across systems) is informative about the event. We correctly perceive the approach of a silent ball. If the acoustic array specified a different time - to - contact than the optic array we would perceive (correctly) a different event. Only the relationship between optic and acoustic stimulation is informative about the true event, not either alone. Many intermodal patterns are not redundant, but all intermodal patterns are informative about events in ways that unimodal stimulation cannot be. In sum, there is always an overall pattern of stimulation across perceptual systems. Events that stimulate one system and not another nevertheless influence the overall pattern. In the context of the overall pattern, nonstimulation of a perceptual system is as informative as stimulation.

We tend to forget this in the laboratory, where we often present stimulation to only a single modality. But the systems that *we* are not stimulating are nevertheless *being stimulated*, and the total pattern of stimulation across all systems is specific to the totality of the situation. Do we suppose that participants confuse our displays for the real thing? This question cannot be answered by appealing to the participants' introspections. We must consider behavior. Warren & Hannon's (1988) participants perceived the direction of "self-motion" in optical displays. But did they *behave* as if they were moving? Did they emit postural adjustments to compensate for the change in the magnitude and direction of the gravitoinertial force vector that must accompany an actual physical displacement? We don't know. I think they didn't, or at least not for long. Was self - motion actually specified in Warren & Hannon's experiments? The total pattern of stimulation across perceptual systems in these studies was uniquely related to a stationary person viewing a display that depicted motion through a simulated environment. (These comments do not undermine the importance of Warren & Hannon's work in demonstrating sensitivity to directional properties of optic flow.)

Intramodal Multiplicity

I have been stressing intermodal stimulation, but it has been suggested that there can be multiple sources of information within as well as across modalities. Pittenger's (1989) three ways of seeing age are a good example (head shape, intraface shape, and head/body ratio). Are these three parameters multiple in the sense of being equivalent or redundant? What happens if separate parameters are specific to

different events, in this case to different ages? What then would be perceived? Most importantly, what physical reality might give rise to such non - redundant stimulation? A dwarf, perhaps? Dwarfs have large heads and small bodies (like young non - dwarfs) but can be any age. Accordingly, the three sources are not multiple or redundant: the relation between them is informative. Redundancy is only one of many possible relations, and may not be the most common. Redundancy among "sources" of information is information for one thing, while non-redundancy among these same sources is information for something else, whether the sources be intramodal or intermodal.

The Specification of Affordances

The potential power of these arguments is revealed when we consider the perception of affordances rather than the pickup of information. The perception of affordances, of opportunities for and consequences of behavior, is what really matters. Imagine that a boulder is coming in your direction. Certainly you would like to know when it will arrive, but that is not all that you want to know. In fact, time - to - contact information, considered in isolation, is useless. Knowing when the boulder will arrive is useful only if you can do something about it. The available behaviors depend on more than the boulder's motion relative to you; they are a function of properties of the situation other than the boulder, properties of the ambient environment and of the self. If you are standing on a flat, level, extended surface of high friction you may be able simply to step out of the way, assuming that you are not excessively fatigued, do not have broken leg, and so on. If the surface of support has other properties, for instance if it is very slippery, the affordance for stepping may be absent, and some other behavior required. Perhaps there is no surface of support. If you are in water you may be able to escape by pushing against the medium o f support, by swimming. If there is no support at all (if you are weightless) there may be nothing that you can do to avoid or mitigate collision. These properties of the situation, and their influence on your affordances for action, will not be specified solely in stimulation of individual perceptual systems, and they will not be specified redundantly across systems (cf. Riccio & Stoffregen, 1988). In order to detect the totality of the event (boulder W approaching you with time - to - contact X in environment Y which affords behaviors Z1, Z2, Z3) you must detect the pattern of stimulation across visual, vestibular, auditory , and somatosensory systems. Only this intermodal pattern specifies the affordances of the situation.

I guess that, in some senses, multiple sources of information exist. It is possible to detect time - to - contact from an optical transformation and/or from an acoustic transformation, and maybe from others as well. But these sources are not redundant, and so do not fit Gibson's or Pittenger's definition of multiple. Moreover, the 'sources' are not detected in isolation: I'm sure it could easily be demonstrated that intermodal invariants influence the perception of affordances in *any* situation. Even if we could detect individual sources of information in isolation, it wouldn't do us much good. Time - to - contact is only one small piece of what the organism needs to detect in order to behave adaptively in the face of impending collision. Time - to - contact is not an affordance, and it does not specify an affordance. Likewise with other information that has been "isolated" within a single modality. We can perceive direction of motion from an optic display (Warren & Hannon, 1988), but direction of motion is not an affordance and does not – by itself – specify any affordance.

Our dependence on intermodal invariants can be inferred from Warren's (1984) work with stair climbing. Warren's participants could perceive the affordance of climb - ability "just by looking at" the stairs. Visually perceived affordances? Not necessarily. Warren showed that affordances for climbing were governed by the relationship between leg length and riser height of the stairs. Did his participants detect leg length solely by *looking at their legs*? Eye height is available optically, but anyone who has flown knows that eye height need not correspond to any property of the body. Leg length is specified in invariant relationships between stimulation of the somatosensory, vestibular, and visual systems (cf. Riccio & Stoffregen, 1988). Warren did not vary the dynamics of the ambient environment, or of the participants' bodies. In fact he went out of his way to eliminate possible effects of fatigue (Warren, 1984, p. 696), which surely cannot be perceived solely on the basis of optical stimulation. Would the affordance (perceived and actual) of climb-ability have varied if the photographed stairs had been covered with glistening oil, or if oil had been poured on the floor on which the participants stood? Would the perceived affordances have varied if the participants were wearing heavy backpacks? The fact that the experimental displays were visual does not mean that the perception of affordances was solely visual. Warren implies as much in his discussion of biomechanical efficiency and the perception of optimal riser height. I do not question the validity of Warren's analysis or of his data. But I do suggest that the perceived affordances in these and many other studies may have been profoundly in-

fluenced by properties of the overall pattern of stimulation across all perceptual systems.

I have not yet addressed our chemoreceptive abilities. The tongue and nose are always operating as well as the eyes, ears, etc. Is stimulation of these organs part of the overall pattern? Sure. Gibson (1966) stressed the fundamentally intermodal nature of gustatory perception. But what about non-gustatory events? As in other systems, the absence of tastes or smells, taken in context of stimulation of other systems, is informative. We have already seen that smell is part of the intermodal pattern of stimulation that specifies combustion. Very few non-gustatory events stimulate the tastebuds. Spatiotemporally homogeneous oral solutes combined with heterogeneity in other forms of stimulation is information for unflavored (or untasted) events, objects or situations.

Conclusion

Are there multiple sources of information? Sometimes, for isolated properties of things. But organisms do not perceive isolated properties. Neither do they perceive sources of information. They perceive affordances. Is there multiple specification of affordances? I believe that there is not, and that there cannot be. To perceive an affordance is to perceive opportunities for and consequences of behavior. We sometimes say that an approaching object "affords collision", as if collision were a property of the object's motion. It is not. The object affords collision *if and only if* we do nothing about it (or nothing adaptive). Passivity is a form of behavior. I have argued that affordances (opportunities for and consequences of behavior) are uniquely (not multiply) specified in the total pattern of stimulation across all perceptual systems. A theory of direct perception, I think, demands the unique (not multiple) specification of affordances: there must be a lawful one-to-one relationship between the pattern of stimulation of (all) perceptual systems and the affordances of a given object, event, or situation for a given organism. If such a relationship exists ambiguity does not exist. I believe that such relationships exist and that they are detected and used by organisms for the adaptive control of behavior. Which aspects of the total pattern are detected, that is, which affordances are perceived in any given situation, will depend on the behavioral goals and perceptual skills of the organism (cf. Riccio & Stoffregen, 1988). It follows (I think) that any and all affordances are specified solely in the intermodal pattern of stimulation across all perceptual systems. This is probably a controversial conclusion, but it may be inevitable.

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