perception of motion relative to the floor that is a function of both mechanical and optical stimulation (combined in the global array) and the postural adjustments would be some function of this perception. If this model were correct, then there would be ambiguity in either single-energy array, as S&B suggest. However, observing postural adjustments in a moving room does not require us to accept this conclusion. The seeming combined influences of gravity and optics may occur in the perceptions themselves. For example, one may have a perception of moving relative to the floor that is influenced both perceptually by the mechanical stimulation from the floor and cognitively by the perception of moving relative to the walls. This option is commonly referred to as percept-percept coupling and does not imply higher-order invariants in the global array. Moreover, the influences of gravity and the optic array could be combined in the generation of the response. For example, imagine that the perception of moving, relative to the floor, is strictly a function of mechanical stimulation; and the perception of moving, relative to the walls, is strictly a function of optical stimulation. The two perceptions do not influence one another directly. Nevertheless, both perceptions may influence the report if the observer is misled to believe that the floor and walls must move together.

Like the authors, we are intrigued by the theoretical possibility of higher-order, or even global, invariants. But S&B fail to demonstrate a compelling empirical basis for their hypothesis. To do this, they must first acknowledge the alternate hypotheses, because these hypotheses remain valid alternatives that must be rejected. Failing to do so could lead to the inappropriate conclusion that there is information-action specificity in a higher-order array when, in fact, the data show only a cognitive effect or a response bias. In the end, it is impossible for S&B to conclude both that specificity in the global array is testable and that it is the only option.

Teleological perception without a biological perceiver?

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Abstract: Strong between- and within-animal differences during spatial activities lead us to claim that a given animal is directly sensitive to a given substructure of the global array. This vicarious subset is not cut out by the senses but by redundancies emerging from physical properties. We argue that the subset is not a single ambient array, or a combination of single ambient arrays, but a complex holistic part of the global array.

The assumption that perception is not divided into separate senses does not imply that animals are directly sensitive to the structure of the global array (GA). This is rather often not the case; because of the animal/environment mutuality, the GA should be broken down or filtered into subsets according to each animal's idiosyncrasy. We assume that these within- and between-animal differences are not linked to senses but to physical properties of the ambient array. In any case, animals can only pick out a subset of the physical reality. Actually, as they are driven by reinforcement (Skinner 1984), their major purpose is to achieve actions, and not merely to extract an accurate perception of the reality, an assumption which would be teleological. Therefore, some subsets of the reality are sufficient and the multidimensional GA is not necessarily systematically sampled out.

Strong between-animal differences both in spatial activities and in spatial disorders provide evidence that senses work in order to give a sufficient idiosyncratic perception based on a functional subset of the GA (Ohlmann & Marendaz 1991). Biological systems (Schull 1990) do not have a predetermined or a priori solution for the world with which they are coping. In mild conditions, such as walking regularly or stabilizing one's posture on a flat resistant surface, redundancies can give rise to precise covariations between the different subarrays. In such a case, a quasi single array is indifferently *sufficient* to control the task. Is there anybody or anything that obliges the animal to work at a higher level? This question has nothing to do with the issue of separate senses. Clearly, in the perception of a subset of the GA such gravito-inertial (GI) forces involve a large set of senses: Golgi receptors, vestibular system, motor proprioception, kidneys (Mittelstaedt 1997), tactile pressures, body fluids, and so forth.

Moreover, in many circumstances there is no need to perceive reality accurately; indeed, action should be easier if one discards some disturbing aspects of the reality. In many cases, animals actively or passively make use of filter-like systems which are brought into play by the characteristics of the situation and/or of the individual.

According to Kimura's "neutralism model" (Kimura 1968; Kimura & Ota 1972), the level of constraints directly entails consequences about the between-animal differences. When an animal is confronted with low constraints, redundancies lead to a vicarious diversity (Reuchlin 1978). Therefore, if some information (data, senses, tools, affordances, part of the GA, etc.) is substitutable for some other information, then a given animal will rely on one kind of information whenever it finds itself in a similar situation.

A clear example of the non-necessity of picking out the GA each time is given by the visual Romberg's Ratio (Amblard et al. 1985). Body movements are successively recorded in total darkness and in illuminated environment. Postural stability is dramatically increased when optics are available. However, there is a strong between-animals variability caused by the extraction of a non-GA, with some subjects (Lacour et al. 1997) keeping the same level of stabilization in darkness and in an illuminated environment. Isableu et al. (1997; 1998) have shown that field-independent subjects (Asch & Witkin 1948) do not need visual information to stabilize their body even in a complex stance. In order to achieve almost the same level of postural control, field-dependent subjects need full optical information. Some subjects appear to be sensitive to both *geometrical and kinematic* optical information (Guerraz et al. 1998), while others rely on *dynamics* (either static or kinetic). These subsets constitute vicarious referents not based on senses but on physical properties of information. Pick (1974) assumed that nonvisual spatial information can be "coded" in a visual mode because of physical properties of optics independent of the visual modality per se. This was expanded by de Volder et al. (1999) who demonstrated that early blind subjects, fitted with ultrasonic devices, exhibited a distinct activity (PET) in the primary visual area. Furthermore, some other subjects showed a high sensitivity to forces, whatever their nature (inertial, frictional, gravitational), which led them to refer primarily to moments of inertia (Pagano et al. 1996), static moments, or gravito-inertial forces. For example, they easily found subjective or postural vertical, either directly by vestibular system, tactile compression, interoception, or by the dynamics of balance (Stoffregen & Riccio 1988; Riccio et al. 1992). Their superiority in any domains involving moto-somato-sensorial control could be easily explained by a postural scheme extracted from the inertial tensor associated with each rotating corporal segment. Finally, this vicariousness even appears at cell level. Waespe & Henn (1977; 1979), showed that in vestibular nucleus of awake monkey, one given cell works either with a visual stimulus or an inertial stimulus, or with a combined visuo-vestibular stimulus.

Why are between-subject differences about motion sickness so dramatic? The postural hypothesis of motion sickness, developed by Stoffregen and Riccio (1991) is unable to account for these dif-

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ferences. In some circumstances, accurate reality or global reality is not helpful for the animal, as is well illustrated by the tilting train. On a curve when the train cabin is quasi aligned with GI force, the subject has the feeling of being upright while the landscape appears tilted (Neimer et al. 2001). This outside visual flow is a useless referent and severe motion sickness can appear even in a seated reading subject. Closing the blinds to reduce the available information suppresses motion sickness by annihilating the conflicting information provided by the two visual referents (cabin and landscape). Actually, a strong correlation appears between motion sickness triggered by a tilting train and motion sickness induced experimentally during a previous exposition to an oblique rotating optokinetic cone (a control cone rotating in pure yaw exhibits no correlation with the train motion sickness). This implies that some subjects who usually rely on visual geometrics (cabin) and kinematics (outside flow) feel an intrasensorial conflict between referents.

In conclusion, it seems that Stoffregen & Bardy's (2001) heuristic approach to perception may appear, in some circumstances, as unrealistic because of its excessive generality. We agree with the view that each situation is specified by the global array; however, we claim that different animals perceive different subsets of specification. In any case, these differences are piloted by the characteristics of the senses. If we take the Gestalt example used in the target article of the perception of a triangle, animals perceive a part of the whole – that is, they perceive an incomplete triangle which is not an isolated element but a sufficient substructure. This might explain why such theoretical positions as amodality, functional modality, intermodality, and multimodality are sometimes simultaneously possible.

On the subject of perceptual illusions, and the ambiguity of perceptual information

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Abstract: Stoffregen & Bardy (S&B) make the point that the statement "I am moving" made by subjects in a "swinging room" cannot be explained as an illusion of motion, and there is thus no perceptual illusion. In this they are correct. There is in fact motion, but of the environment. We argue that the subjects misinterpret this because the information to the visual system is ambiguous and also deceiving.

In their target article, Stoffregen & Bardy (S&B) (2001) discuss the frames of reference for motion and use as an example perceptual illusions. They suggest a reinterpretation of subjective reports of physical motion, which are to be found in studies in which perceptual information is manipulated (e.g., Dichgans & Brandt 1978; Lishman & Lee 1973).

The statement "I am moving," reported by subjects in the above-mentioned experiments, is said by S&B to be ambiguous because there is more than one frame of reference. The "swinging room" (Lishman & Lee 1973) or "rotating drum" (Dichgans & Brandt 1978) is one reference frame (the illuminated environment), and the earth is another. S&B say that subjects stating "I am moving" are correct because they are in motion relative to one of the relevant reference frames, namely, the illuminated environment. This interpretation we consider to be wrong – at least when, like S&B, we are not talking about normal postural sway. What is really ambiguous is not the statement "I am moving" but the perceptual information. The problem that subjects encounter in the described situation is that the visual system cannot uniquely specify motion relative to the environment as self-motion. Gibson (1968) suggested that one possible way for the visual system to distinguish between self-motion and motion of the environment is to detect part-whole differences: "motion perception caused by locomotion entails change in the whole of the textured ambient array whereas the alteration of perspective caused by an objective motion entails only change in part of the ambient array, the remainder being frozen" (p. 187). In the Lishman and Lee (1973) and Dichgans and Brandt (1978) studies, there are no such part-whole differences because the whole room (or drum) is being moved. A change in position relative to the environment, therefore, looks exactly the same whether the change is caused by self motion or is caused by motion of the environment. This is exactly what the subjects encountered. The change in position relative to the environment was caused by motion of the environment and not by any movement, active or passive, of the subject.

When subjects are faced with such a situation, they most often misinterpret this relative motion as self-motion. We argue (cf. Pedersen 1999; 2000) that this is not because – as Lishman and Lee (1973) and later Lee and Aronson (1974) and Lee and Lishman (1975) suggested – the visual system is the dominant system. Neither is it because, as S&B argue, the subjects are in motion relative to the (illuminated) environment, or relative to anything for that matter. It is because the information provided to the visual system is ambiguous, and in this situation, also deceiving.

S&B would, however, seem to be right when they state that this is not a perceptual illusion because there is, actually, motion; therefore, the perception is correct. The subject's visual system does detect motion of the room. The mechanical proprioceptors are also correct because they detect that the body is stationary, and they are not concerned with motion of the room at all. Why would the subject, then, interpret this as self-motion? The problem lies, as mentioned, in the information, which is deceiving because the fact that the room moves is inconsistent with all the subject's experience so far, whether as infant (Lee & Aronson 1974) or as adult (Dichgans & Brandt 1978; Lee & Lishman 1975; Lishman & Lee 1973). This means, in Gibson's (1966) terms, that a genuine biological invariant ("rooms do not move") has been destroyed. In such a situation, says Gibson, a subject must either accept the visual information and reject the postural (mechanical), or accept the postural (mechanical) and reject the visual, or alternate between the two, or compromise between the two. Of course, still according to Gibson, the subject may sometimes just be confused (Gibson 1966, p. 297). In the studies referred to (Dichgans & Brandt 1978; Lishman & Lee 1973), the subjects perceived that something was, in fact, moving, and they reasoned that it could not (at least it should not) be the room (or drum). The information was, therefore, interpreted as propriospecific when it was actually exterospecific.

On ventriloquism, audiovisual neurons, neonates, and the senses

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Abstract: The analogy between the rules that subtend ventriloquism and bimodal neurons responding suggests a possible neural mechanism for audiovisual interactions in spatial scene analysis. Perinatal data, such as those on synesthesia, sensory deprivation, and sensory surstimulation, as well as neuroanatomical evidence for transitory intersensory connections in the brain support the view that audition and vision are bound together at birth.

As illustration of sensitivity to patterns that extend across the acoustic and optic arrays, Stoffregen & Bardy (S&B) (2001) quote the McGurk effect observed in speechreading (McGurk & McDonald 1976). Additional evidence is provided by the ventrilo-

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