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Recasting Dewey's critique of the reflex-arc concept via a theory of anticipatory consciousness: implications for theories of perception

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Abstract

Dewey (1896) claimed that the word stimulus, if it is to be used in descriptions of organism–environment coordinations at all, should be used to refer, not to environmental events, but rather, to that aspect of the coordination specifying the state of affairs the coordination is striving to maintain. The present paper recasts Dewey's critique by claiming that this specifying aspect of the coordination resides within a continuously generated, anticipatory body-in-the-environment "feel" that is not the result of afference. This theory of anticipatory consciousness is based primarily upon a synthesis of (1) Vandervert's (1995) neuropositivistic integration of Lotka's (1945) theoretical arguments regarding the prey-predator scenario, and Melzack's (1992) empirical work on phantom limbs, and (2) research on a recently reported perceptual phenomenon known as the Phantom Array (Hershberger, 1987), the existence of which supports the theory of anticipatory consciousness. This recasting of Dewey's coordination-specifying "stimulus" is then used to reveal conceptual inadequacies that arise within representationalist theories of perception, for such theories tend to ignore Dewey's critique and theorize perception to be a response to environmental stimuli. Such theorizing leads to the following inappropriate conclusions: (1) perception lags behind the world, (2) the perceiver's view of the world is inherently inaccurate and incomplete, and (3) there exists a "physical" world of which we experience but appearances. The presented theory of anticipatory consciousness reveals that (1) the sequencing of perception is determined more by the control of body–environment relationships than by the moment of information transduction (i.e., transfer delays), (2) perceptual accuracy should be measured in terms of sensory-motor success versus the degree of correspondence between mental representations and the material world, and (3) the "objects" found in the world beyond the organism are not ontological, a priori "givens" in need of representation prior to entering phenomenology, but rather, are invariant thermodynamic "information structures" that find themselves "realized" within an organism's field of control. Based on these arguments, it is then concluded that it is the *material* world, not

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perception, which qualifies as inference, and J. J. Gibson's theory of direct perception, which does not demand the inference of a "material" world is, thus, the more parsimonious. © 1998 Elsevier Science Ltd. All rights reserved.

1. Introduction

Almost 100 years ago to the date, John Dewey (1896) published his seminal review: "The Reflex-arc Concept in Psychology". In that paper, Dewey made clear the peculiar way one must describe human action when constrained to the stimulus–response distinction. The problem, he felt, was that the words stimulus and response represented nothing more than conceptual abstractions from what was an otherwise continuous, coordinated sequence of events. Descriptions of action based upon these abstractions, claimed Dewey, stripped the coordination of its very essence; namely, the process of maintaining a particular state of organization. Thus, he proposed that action be modeled, not as a linear chain of stimulus-response contingencies, but rather as a circuit (i.e., an organized coordination) whose outputs are fed back into the system as inputs. According to Dewey then, instead of using *stimulus* to refer to an external event, it should be used to refer to that part of the coordination which specifies the state of affairs (i.e., state of organization) the coordination is maintaining, while *response* should refer to that aspect of the coordination which serves as the means by which the specified state of affairs is maintained:

The stimulus is that phase of the forming coordination *which represents the conditions which have to be met in bringing it to a successful issue* [italics added]; the response is that phase of one and the same forming coordination which gives the key to meeting these conditions, which serves as instrument in effecting the successful coordination (as quoted in Sahakian, 1968, p. 225).

The purpose of the present paper is to present a recasting of Dewey's critique by bringing together data which shed light on the nature of Dewey's coordination-specifying "stimulus". This will be accomplished via a synthesis (Jordan, 1996) of Vandervert's (1995) neuroalgorithmic theory of anticipatory consciousness and a series of studies on a recently reported perceptual phenomenon known as the Phantom Array (Hershberger, 1987). This synthesis will reveal that the primal stimulus within any organism–environment coordination resides within a continuously generated anticipatory "feel" of the body in space-time that is not derived from afference (i.e., it is not a "caused-effect" of "environmental stimulation"), yet is essential to controlled action.

Having made this point, the paper will then address the implications of this anticipatory phenomenal context for *theories* of perception. It should be stressed that the present paper does not challenge traditional stimulus-response *methodology*. The practice of manipulating and controlling independent variables in order to assess their relationship to dependent variables has proven invaluable in its ability to reveal

dynamic contingencies between the observations of physicists and that which we find in common phenomenology; an endeavor traditionally referred to as psychophysics. What the present paper does challenge is the literal translation of these *methodological* concepts into *theoretical* concepts. That is, once perception is *theorized* to be a response to environmental stimuli, as is often done in what are perhaps best known as *representationalist* theories of perception (Costall, 1984), it appears theoretically appropriate to assume that (1) perception “lags” behind the environment, and (2) perception is inherently inaccurate because the perceptual response (i.e., representation) cannot be equal to the total environmental stimulus available. The recasting of Dewey’s critique counters these arguments, and further makes it clear, in a new way, that this sort of representationalist theorizing results from the non-parsimonious assumption that perception is the process of constructing “appearances” of the real, physical world. The paper will conclude by making the argument that it was just this sort of non-parsimonious theorizing that J.J. Gibson (1979) was attempting to overcome in his theory of direct perception.

2. Phantom limbs and the phantom array: Evidence of the anticipatory nature of consciousness

As one looks from one target to another within the visual environment via saccadic eye movements, the spatial location of a stationary object appears to remain stable despite the fact that the retinal locus of the object’s image changes with each change in eye position. Researchers claim that the nervous system achieves this perceived constancy across saccades, what is perhaps best known as visual direction constancy (VDC) (Shebilske, 1976) by producing a corresponding shift in the spatial coordinates of the retina (i.e., retinal local signs) via a neural signal representing eye position (Bridgeman, 1986; Grüsser, 1986; Hallet and Lightstone, 1976a,b; Hansen and Skavenski, 1985; Hershberger and Jordan, 1992, 1996, 1998; Hershberger et al., 1998; in press; Jordan and Hershberger, 1994; Matin, 1972, 1982; Shebilske, 1976; Skavenski, 1990; Steinbach, 1987). Given that the true nature of this neural signal is unknown, it is often referred to as the *extraretinal* signal.

Interestingly, researchers are now claiming there to be a similar sort of signal for the entire body; an *extrabody* signal that codes the coordinates of the body in space-time (Melzack, 1992; Stapp, 1993; Vandervert, 1995). Melzack (1992) models this *extrabody* signal as a hard-wired neuromatrix spread-out over three major brain circuits that continuously generates a pattern of impulses letting one know, “the body is intact and unequivocally one’s own” (p. 123). Vandervert (1995), referring to the work of Melzack, refers to this *extrabody* signal as a “continuously generated feedforward template of the active body universe” (p. 113). He then claims that the activity of this continuously generated template of the body in space-time constitutes one’s basic level of awareness of one’s self as something different from the environment; that is, it is *consciousness*:

I propose that conscious experience is the continuously generated entirety of the activity of the pure space-time template of the body in the brain – it

feeds forward the integrity and ‘whereabouts’ of the genetically-derived template of the body universe. (p. 113)

3. Theoretical underpinnings of Vandervert’s theory

Vandervert refers to the activity of this proposed space–time template as a *neuro-algorithm*, and points out that the phylogenetic emergence and genetic embedding of such a neuroalgorithm is the result of millions upon millions of selective iterations, over the course of evolution, of what Lotka (1945) referred to as the prey–predator scenario (Fig. 1).

Survival within this scenario demands that both the prey and the predator be able to discriminate changes in perception brought about by self-motion versus environmental motion, what von Holst and Mittelstaedt (1950) referred to as refference and exafference, respectively (cf. Hershberger, 1998). It further demands that the neuroalgorithms regarding the body in space–time that are used in making this refference–exafference distinction, be feedforward (anticipatory) in nature. The predator must control the motion of its body as a whole towards positions it anticipates the prey will occupy, while the prey must accomplish the same feat, but toward positions it anticipates the predator will *not* occupy. Vandervert believes it was the need for this organism–environment, refference–exafference sort of figure–ground distinction that brought about the emergence of such anticipatory (i.e., feedforward) body-in-space-time neuroalgorithms:

It is my view that consciousness constructs this model of space time in the brain as a comparator system by which the brain can movement-by-movement, moment-by-moment differentiate itself from, and make sense of, the constant barrage of incoming sensory information ... (1995, p. 113)

4. Phantom limbs: Empirical support of Vandervert’s theory

As evidence of this continuously generated neurotemplate of the body in space–time, Vandervert (1995) cites Melzack’s (1992) work on phantom limbs. Melzack points out the following: (1) A person missing a limb continues to experience the limb as if it were still intact, (2) the phantom limbs are experienced in spatial locations that are consistent with the person’s ongoing behavior, and (3) loss of a limb is not necessary: phantom limbs are also experienced by those who are born without a limb. From these findings, Melzack concluded,

the existence of phantoms in people born without a limb or who have lost a limb at an early age suggests that the neural networks for perceiving the body and its parts are built into the brain. The absence of inputs does not stop the networks from generating messages about missing body parts; they continue to produce such messages throughout life. (p. 126)

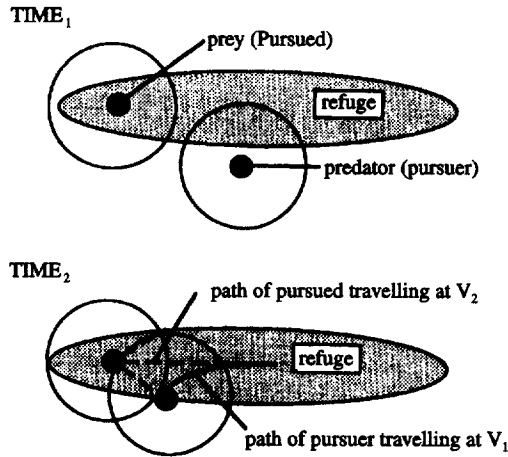


Fig. 1. “Countless millennia of iterations of selective processes in this generalized prey–predator scenario resulted in the encapsulation of space–time algorithms in the brain. Algorithms are patterns of energy pathways (methods of work) that solve problems.” (Figure and quoted caption from Vandervert (1995). Reprinted by permission of the publisher and the author.)

Investigations of a recently discovered perceptual phenomenon known as the Phantom Array (Hershberger, 1987) further support this notion of a continuously generated neuroalgorithmic template of the body in space–time. The Phantom Array also provides empirical evidence which supports the notion that the template is a template, not of *actual, proximal limb position*, but rather, of the *intended, distal action* in which the limb is to be engaged. The “feel” of the body in space–time, then, is the moment-to-moment discrepancy between the anticipated and the actual location of the body in space–time.

5. Further empirical support of Vandervert’s theory: The phantom array

One experiences the phantom array while producing saccadic eye-movements across a rapidly blinking (200 Hz) light-emitting diode (LED) in an otherwise darkened room. While saccading from left-to-right, one sees something akin to that depicted in Fig. 2 (Hershberger and Jordan, 1998). Specifically, one sees a horizontal row of flashes in which the flashes materialize sequentially in the direction opposite the saccade. This, of course, is brought about by the sweeping motion of the retina across the blinking LED. However, the fact that one sees an array indicates that the shift in eye-position and the shift in the extraretinal signal (i.e., space–time template of retinal spatial coordinates) are asynchronous, for if they were synchronous, the retinal local signs would be shifted in the direction of the saccade at the same rate as the eye, and every flash would appear at the same spatial location. The nature of this asynchrony can be deduced to some extent from the spatial location of the phantom

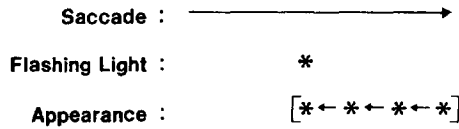


Fig. 2. "If you shift your gaze saccadically from the left to the right of a point light source in a darkened room, blinking on and off at 120 Hz, you will see phi movement to the left within a phantom array that is *displaced* to the right." (Figure and quoted caption from Hershberger (1987). Reprinted by permission of the publisher and the author.)

array. Specifically, the entire array appears on the side of the LED associated with the intended direction of gaze (Hershberger and Jordan, 1992, 1998), with the first flash appearing abruptly displaced from the pre-saccadic location of the LED to its position at the right-end of the array. Given that the first flash is presented at or before the moment the eyes begin the saccade (this is assumed from its appearance as part of the array which, of course, is brought about by the actual movement of the eyes), its abrupt displacement in the direction of the impending saccade indicates that by the onset of the saccade, the local signs of the retina have shifted in the direction of the impending saccade. Jordan and Hershberger (1994) conducted an experiment to determine when this anticipatory shifting of the template occurs.

5.1. *Timing the template*

Four trained subjects produced 1600 left-to-right saccades in the dark from a fixation point (F) to a saccadic target (T). The spatial layout and the onsets and offsets of all stimulus LEDs are depicted in Figs. 3 and 4, respectively (for a thorough examination of the methodology, see Jordan and Hershberger, 1994). At the start of every trial, F glowed red for a randomly varied interval ranging from 1–2 s (the unpredictable duration of F reduced the frequency of anticipatory saccades). As can be seen in Fig. 4, exactly 50 ms following the offset of F, T glowed red for 100 ms. Subjects, having been told to "follow the red light" saccaded (S, Fig. 4) from F to T. A 150–250 ms latency normally exists between target onset and the actual initiation of a saccade (Robinson, 1975); consequently, both F and T were extinguished before the eyes began to move.

The LED labeled AL (Array Light) began flashing green at 200 Hz, 5 ms after the subject began the saccade from F to T, and stopped flashing 1 ms after the subject completed the saccade (see Fig. 4). This green flashing LED produced a green phantom array. The two LEDs labeled M (Marker) flashed simultaneously for 1 msec at a pre-determined moment during the trial. As can be seen in Fig. 4, there were 20 possible moments for each subject, each being separated by a 10 ms interval. This "window" of potential marker moments was temporally situated around the subject's average saccadic latency, which had been determined prior to the onset of experimental trials (Fig. 4 depicts a hypothetical subject having an average saccadic latency of 180 ms). The actual marker moment utilized on any given trial was unknown to the subject. The pair of yellow marker flashes produced by the Ms generated a vertical yellow hash-mark that intersected the green phantom-array. Given that these yellow

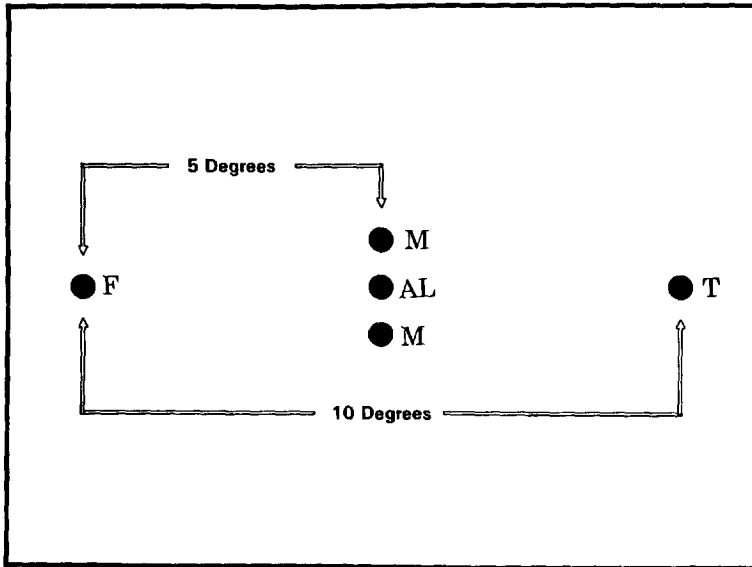


Fig. 3. “Arrangement of LEDs used to generate visual displays. F = fixation light, T = Target light, AL = array light, M = Marker.” (Figure and quoted caption from Jordan and Hershberger (1994). Reprinted by permission of the Publisher.)

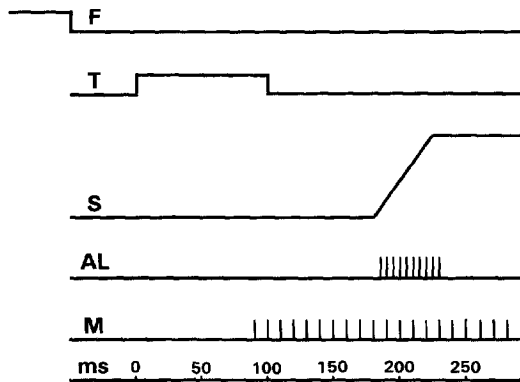


Fig. 4. “The chronology of events comprising a single trial. F = fixation, T = target light, S = saccade from F to T, AL = array light, M = marker flash; the bottom trace indicates milliseconds in relation to T onset.” (Figure and quoted caption from Jordan and Hershberger (1994), Reprinted by permission of the Publisher.)

flashes would be displaced just as the green flashes had been, and further given that one could, in a post-hoc manner, determine the moment of the M flash in relation to the onset of the saccade, the location of the yellow hash mark within the green phantom array provided a reliable measure of when the first flash (or any flash for that matter) in the phantom array appeared, relative to the onset of the saccade.

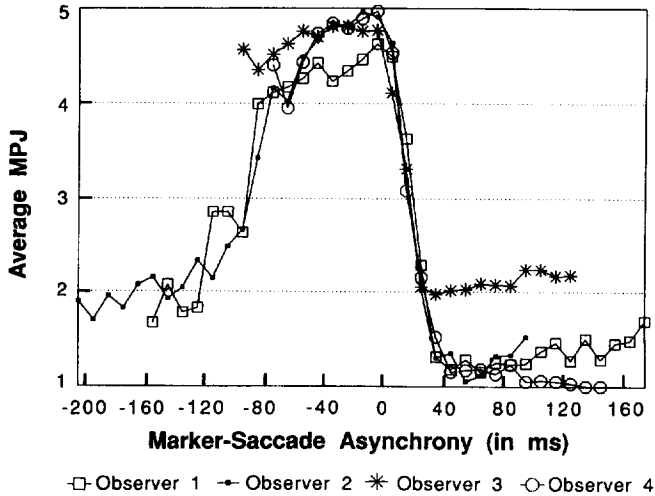


Fig. 5. “The observer’s average marker-position judgments (MPJs) plotted as a function of the marker-saccade asynchrony.” (Figure and quoted caption from Jordan and Hershberger (1994). Reprinted by permission of the Publisher.)

To obtain this measure, subjects indicated where the yellow vertical line had appeared relative to the phantom array. They did so on a 5-point scale on which a 1 meant “the left-end of the array”, a 5 meant “the right-end of the array”, and a 3 meant “the middle of the array” (2 and 4, of course, meant positions between 1 and 3, and 3 and 5, respectively). Fig. 5 illustrates the change in the average Marker-Position Judgment (MPJ) as a function of the temporal relativity of M and the saccadic onset (Marker-Saccade Asynchrony; MSA).

5.2. *Illustrating the shift in the template*

The first thing to point-out about Fig. 5 is the pattern of MPJs during the saccade (i.e., MSAs ranging from 0 to 40 ms). Clearly, markers flashed at the beginning of the saccade were seen at the right end of the array, while markers flashed during the saccade (i.e., MSAs between 0 and 40) were seen at array locations nearer and nearer to the left-end of the array. The extreme overlap of the 4 subjects during this range of MSAs rather robustly indicates that subjects were very capable of judging the location of M within the phantom array, and further serves to validate the MPJs obtained at different MSAs. For example, during the 80-ms interval preceding the onset of the saccade (i.e., MSAs of -80 to 0), the MPJs are very close to 5. This indicates that Ms flashed as soon as 80 ms prior to the onset of the saccade were seen at the right-end of the array, which further indicates that the first flash in the phantom array appears in its displaced location roughly 80 ms prior to the onset of the saccade. Given that the subjects were still fixating F during this interval, the appearance of the first flash in this new displaced location indicates that the space-time template of the retina had

shifted in the direction of the *impending* eye-position, despite the fact that the eyes had yet not begun the saccade that would bring them to that impending position.

Clearly, the shift in retinal local signs accompanying a saccade is anticipatory. Further support for this claim can be found in the work of Becker and Jürgens (1975), for they found that the amplitude of a saccade may be altered by retinal information that is presented as late as 80 ms prior to a saccade, indicating that the shift in retinal local signs is finalized just in time to generate the pre-saccadic portion of the Phantom Array. Further, Duhamel et al. (1992) reported finding neurons in the monkey inferior–parietal lobe that shift their retinal receptive fields to the same degree and in the same direction as an impending saccade well before the onset of the saccade (e.g., 80 ms or more). Collectively, these data support the claim that the shift in the template is anticipatory, and led Jordan and Hershberger (1994) to conclude the following:

The traditional interpretation of the perisaccadic illusion of visual direction is that the brain shifts the retinal local signs in order to compensate for an eye movement, and generally dismisses the alternative possibility that the brain moves the eyes saccadically in order to compensate for an abrupt shift in retinal local signs (p. 665).

6. The anticipatory nature of consciousness

Both phantom limbs and the Phantom Array indicate that “felt” egocentric space (i.e., phenomenal body-in-space-time experience) is “of”, or “about”, the discrepancy between intended and actual body-in-space-time location, with shifts in the former preceding shifts in the latter. This supports Vandervert’s (1995) claim, derived from the “flight” and “pursuit” curves of the Lotka scenario, that the continuously-generated template of the body in space–time is feedforward (anticipatory) in nature, and further indicates that our immediate awareness of ourselves in space–time, which Vandervert (1995) claims is consciousness, resides within the discrepancy between the actual, proximal position of the body in space–time, and the distal, intended action in which the body is to be engaged.

This notion that experience is influenced by both intended and actual effector-position is not completely new. Helmholtz claimed as early as 1867 (1962) that perceived visual direction depends more upon the “effort of will” necessary to produce eye movements than upon proprioceptive feedback. This hypothesis has often been cited as being synonymous with von Holst and Mittelstaedt’s (1950) efference copy hypothesis, which claims, essentially, that the extraretinal signal (neuroalgorithmic template) mediating visual direction constancy is a copy of the neural commands sent to the oculomotor nuclei (Dassonville et al., 1992; Hallet and Lightstone, 1976a,b; Hansen and Skavenski, 1985; Honda, 1989; Matin, 1972, 1982; Shebilske, 1976).

The existence of phantom limbs and the Phantom Array, however, challenge the idea that it is a copy of *efference* that is feedforward. Specifically, the fact that subjects experience phantom limbs in positions consistent with on-going behavior, despite the lack of the limb, indicates that the template of the body-in-space-time is a template of

“feels” that *are not derived from afference*. This is consistent with Melzack’s interpretation of Phantom Limbs:

In short, phantom limbs are a mystery only if we assume the body sends sensory messages to a passively receiving brain. Phantoms become comprehensible once we recognize that the brain generates the experience of the body. Sensory inputs merely modulate that experience; they do not directly cause it. (1992, p. 126)

Since these “feels” are not the result of afference, one might be tempted to refer to the neuroalgorithms mediating such “feels” as efference. And since both Lotka’s prey-predator scenario and the phantom array indicate these “feels” are anticipatory, one might further contend that the involved neuroalgorithms constitute an anticipatory *efference copy*. But this is also problematic, since *efferent* signals are traditionally associated with effector movement, not effector “feels”. It seems as though the neuroalgorithms mediating these anticipatory “feels” are neither afferent nor efferent, at least not in terms of the *inflow* and *outflow* they traditionally denote.

Hershberger (1976, 1998) was aware of this problem with efference-copy explanations of spatial constancy. Thus, he coined the phrase *efference copy* in order to capture the idea that the neuroalgorithm mediating constancy was an anticipatory “feel” versus an anticipatory motor command (efference-copy). This notion of an anticipatory “feel” of an effector in space time is precisely what was eluded to by William James in his classic description of voluntary behavior;

I trust that I have now made clear what that ‘idea of a movement’ is which must precede it in order that it be voluntary. It is not the thought of the innervation [efference copy] which the movement requires. It is the anticipation of the movement’s sensible effects [afference copy], resident or remote, and sometimes very remote indeed. (1890, Vol. 2, p. 521)

The nature of these anticipatory “feels” and their relationship to what is traditionally denoted by *afference* is made clear by research on perceived visual direction during oculomotor paralysis (Stevens et al., 1976; von Graefe, 1854). Specifically, those experiencing anatomical or neurochemical oculomotor paralysis report that the visual scene seems to “jump” in the direction of an attempted saccade, yet do not report that the visual world remains in this position for long. Apparently, feedback from the un-moved orbs keeps the generation of the afference-copy in “check”, and thus prevents long-term experience of phantom-like phenomena. This notion is supported by the existence of phantom limbs. Specifically, the feedforward neuroalgorithms of the body in space-time are present, while feedback is not. Given this de-coupling of the neuroalgorithms regarding intended and actual effector location, the generation of anticipatory “feels” continues “unchecked” as it were, and the missing limb is experienced in positions consistent with on-going behavior (i.e., the intended orientation of the rest of the body). Thus, while the Phantom Array is brought about by the relatively brief de-coupling of intended and actual eye-position that exists both before and during saccadic eye-movements, phantom limbs are the result of the same sort of de-coupling playing itself out at a temporally-larger, more

permanent scale. And this de-coupling is not between an efference-copy and feedback. It is between an anticipatory efference-copy and feedback.

7. Implications of the anticipatory nature of consciousness for theories of perception

This notion of an anticipatory feedforward “feel” of the body in space-time provides new insight into Dewey’s (1896) claim that the word *stimulus* should refer to the part of the organism-environment coordination specifying the state of organization the coordination is striving to maintain. *If the word stimulus is to be used, it should refer to the anticipatory “feel” of the body in space-time the organism is specifying and striving to attain.*

This recasting of Dewey’s critique has profound implications for theories of perception, for it reveals conceptual shortcomings that arise within representationalist theories which claim that perception is the act of generating mental/neural representations in response to environmental stimuli. Such representationalist theories are perhaps well-represented by the following quotation:

... perception consists of a sequence, stretching from events in the physical world external to the perceiver through the translation of those events into patterns of activity within the perceiver’s nervous system, culminating in the perceiver’s *experiential and behavioral reactions* [italics added] to the events. (Sekular and Blake, 1994, p. 1)

These authors later state the following:

The perceiver’s view of the world is necessarily inaccurate, because the perceiver’s sensory system both *limits* the information that is available and *augments* the information that is available. . . . To sum up: In order to understand perception as fully as possible, one must study not only the properties of the physical world but also those of the perceiver. (p. 11)

Even though the word representation is not utilized in the preceding quotation, there is an obvious commitment to the representationalist notion that perception is a response to an environmental stimulus. The anticipatory, feed-forward “feel” of the body-in-space-time, revealed via phantom limbs and the phantom array, makes clear three conceptual shortcomings inherent within such a theory of perception. The first is its sequencing of environmental awareness. The second is its claim that the perceiver’s view of the world is necessarily inaccurate. And the third is its implicit assumption that there exists a real “physical” world of which we experience but appearances.

8. The sequence of perception

Implicit in the sequence outlined in representationalist theories of perception is the notion that awareness of the world necessarily lags “behind” the world due to the transfer delays of the nervous system. Though the notion of transfer delays seems appropriate, the notion that perception is thus a post-hoc phenomenon, does not. The

locations of the flashes in the phantom array clearly indicate that those flashes occurred within an anticipatory (feedforward) phenomenological context; 80 ms prior to the onset of the saccade, phenomenal space had already shifted in the direction of the intended direction of gaze.

This notion that perception is constrained and contextualized by control of the body in space-time was touched upon by Dennett (1991) in his critique of Libet's (1981) arguments regarding the temporal relationship between environmental events and perception. Specifically, Dennett claims that the temporal order, or sequence, in which the nervous systems distributes information is not dictated by the order in which the information is transduced by the sense organs. Rather, it is dictated by the temporal constraints imposed by the on-going control of the body in space-time. Dennett refers to these constraints as "temporal control windows" and contends that the nature of these windows is a function of the relevant sensory-motor coordination.

When we are engaged in some act of manual dexterity, 'fingertip time' should be the standard; when we are conducting an orchestra, 'ear time' might capture the registration. (p. 162)

Phantom limbs and the phantom array enhance Dennett's contention by pointing out that whatever we "experience" about these temporal control windows is contextualized by the changing intended orientation of the body in space-time. For example, as regards "saccade time" the temporal-control window "opens" with the observer's decision to look to a new position, and closes roughly 80 ms prior to the onset of the saccade, from which point the afference-copy "jumps" and becomes "locked-in" at the intended direction of gaze. Visual experiences unfold as if the eyes have moved in the direction of the intended saccade, and subsequent retinal information (i.e., the phantom array), that reaches the appropriate thresholds, is experienced within the context of this locked-in, intended "feel." Further, even though the *visual* location of a perisaccadic flash follows the pattern made clear by the Phantom Array (i.e., it is illusory), one can nonetheless accurately point (Miller, 1993) and guide hammer blows (Hansen and Skavenski, 1985) toward the location of such flashes. These data indicate that "saccade-time", "manual-pointing time", and "hammer-blow time" function according to control windows involving different levels of temporal scale, and the sequence of perception within such windows is determined more by the temporal scale of that window than temporal constraints imposed by transfer delays.

Interestingly enough, there are data to indicate that even though these control windows operate at different temporal scales, they are, nonetheless, coordinated and can influence one another. Specifically, Lucas (1994) found that a brief (1 ms) perisaccadic flash presented at the onset of a saccade to a target located 8° from the fixation point, can result in hypermetric adaptive saccades even though the perisaccadic flash originates from a hypometric location (e.g., 6° from the fixation point). The perisaccadic flash must be presented during the de-coupling of intended and actual eye position (i.e., from roughly 80 ms prior to the saccade to the end of the saccade), because hypometric flashes presented at the end of the saccade produce hypometric adaptive saccades. Further, the peri-saccadic flash must be brief, for if it is presented at saccadic onset and lasts an entire second, the result is hypometric adaptive saccades.

Thus, in order for the flashes comprising the phantom array to impact eye-movements, they must be presented in isolation during the de-coupling of intended and actual eye position.

How does one use the words *stimulus* and *response*, or *cause* and *effect* to describe the sequence of perception that is playing itself out among these temporally nested control windows? Once can rightfully make the methodologically oriented statement that the flashes comprising the phantom array constitute an effect of the blinking LEDs. However, one can also rightfully state that the spatial extension of the flashes comprising the array constitutes an effect of the interaction between the subjects' intended and actual action. In the former description, the environment constitutes stimulus, while in the latter, the organism does so. Some might be satisfied by declaring a draw and making the claim that perception is influenced by both environmental stimuli and top-down influences residing within the subject. But such thinking makes it appear as if both environment and organism are imbued with equal causal efficacy. The question is, are they?

Prinz (1997) addressed this issue directly. His claim is that in any experimental setting, the first and primary stimulus is to be found in the instructions given to the subject. Thus, in the Phantom Array experiment, the instructions given to the subjects to follow the red lights and to assess the location of the hash mark relative to the marker flashes, provided subjects with a sensory-motor coordination to maintain throughout the experimental session. *This is how the LEDs obtained their status as stimuli*. If the subjects had been placed in the experimental laboratory without having been asked to maintain the afore-described sensory-motor coordination, the LEDs would have had minimal, if any, causal efficacy in regards to the subjects' perceptions.

Costall (1984) too, was aware of the primacy of the subject's perceptual expectations and the fact that such expectations are manipulated within experimental settings;

...the psychological laboratory is the very microcosm of the Cartesian scheme [environment as stimulus]. After all, our major experimental paradigms are designed explicitly to prevent the organism from transforming the experimental situation, as would be possible to some degree in real life...The subjects are free only in the sense that they can *react to*, [italics added] rather than change, the conditions which are imposed upon them.
(p. 114)

This point may appear contrived and trivial, but it brings to a head, rather robustly, the fact that in experimental settings, environmental events derive their conceptual power as stimuli via experimental instructions. Of course, this is the very purpose of experimental control – to minimize the subject's contribution to his/her own experiences. By doing so, one assumes one's experiment to be revealing phenomenally independent “physical-world” parameters which serve as the causes of perception. This methodology may sound atheoretical, as if one is simply sticking close to the “facts.” But the statement, in fact, implicitly makes the theoretical claim that perception is an effect of environmental causes. This philosophical maneuver makes it appear equally “factual” to claim that perception lags behind the world due to transfer

delays. The only place this statement approaches being appropriate is in a laboratory setting in which the subject's contribution is supposedly minimized.

Environmental events are ultimately granted causal efficacy because such events are relevant to an organism's controlled sensory–motor coordination. The maintained sensory–motor coordination (i.e., intention, afference-copy, etc.) is the final cause. It is the primary stimulus. An organism controlling its relationship to the environment predetermines, via its intentions (i.e., afference copies), which environmental events have the potential to influence that control. We can *refer* to those environmental events as stimuli, but we cannot theorize such environmental events to be the causes of perception, for newly-detected environmental information always resides within a world of phenomenal body-in-space–time anticipation. Transfer delays do exist, but the “pursuit” and “flight” curves of the prey–predator scenario clearly indicate that natural selection favors those systems whose phenomenology plays itself out on the forward, anticipatory edge of the present. Phantom phenomena indicate that this anticipatory edge is provided by the anticipatory feels associated within temporally nested control windows. And as pointed out by Hershberger (1976) and James (1890), such “anticipatory images” are a necessary prerequisite of controlled action.

This notion, then, that perception begins with an organism's need to control, leads to the second conceptual inadequacy that the present recasting of Dewey's critique reveals about the representationalist tendency to utilize *methodological* stimulus–response distinctions within *theories* of perception. That it, it challenges the notion that an organism's perceptions are necessarily inaccurate because the organism's sensory systems augment and limit the information transduced.

9. Perception as limited and inaccurate

The claim that perception is necessarily limited and inaccurate is based upon the fact that organisms cannot transduce all of the information available within the environment, thus, any “representation” they construct of that world must be inherently incomplete (i.e., inaccurate). This definition of perceptual accuracy, however, results from labeling the environment as stimulus and perception as response – perception is theorized to be an act of representation construction. If the intentions of the organism are labeled as stimulus, however, perceptual accuracy becomes something different. For if environmental information is transduced according to its relevance to the control of body-in-space–time relationships, perceptual accuracy comes to be measured in terms of sensory–motor success. Over the course of evolution, success on this scale has been dictated by the dynamics of the prey–predator scenario, with successful sensory–motor coordinations being those that lead to escape for the prey, and capture, for the predator. Vandervert (1996) discusses how these successful neuroalgorithms (sensory–motor coordinations) come to be:

..a given algorithm is independent of its source system and can be moved from system to system by purely algorithmic processes. For example, algorithms which obtain among systems of physical sources of nature do

not in any way ‘belong’ to those systems, and they may be transported from those dynamical nonliving substrates into substrates of living systems such as nervous systems by another algorithm, for example, the ‘natural selection algorithm.’ (p. 5)

Thus, countless selective iterations of the prey–predator scenario (the algorithm of “natural selection”) have resulted in sensory–motor coordinations (neuromuscular algorithms) whose dynamics are a mirror image of the forces, or dynamics, they must counteract in the environment (environmental algorithms). “Accurate” perceptions within these successful sensory–motor coordinations would be those perceptual events that facilitate “escape” and “capture” for the prey and predator, respectively.

As regards perception of the body, phantom phenomena indicate that the “accurate” way to perceive the body is in terms of the discrepancy between its “intended” and “actual” location, thus allowing the control of anticipatory “flight” and “pursuit” paths. Given these paths must be directed toward locations the prey and predator are expected to occupy or not occupy, respectively, it follows that what organism’s specify to be “attained” is not just body-position, but rather, body-in-environment position. This means that both body and environment locations must exist within an anticipatory phenomenal context.

Recent studies in cognitive psychology support this notion. Specifically, it has been demonstrated (Freyd and Finke, 1984; Finke et al., 1986; Hubbard, 1995) that the remembered final position of a moving target is displaced in the direction the target was traveling just prior to its offset. Further, the magnitude and direction of the displacement is consistent with the laws of physics. For example, the remembered final position of an upward-traveling target is displaced in the direction of the target’s motion, but to a lesser extent than a downward-traveling target. This, of course, is consistent with the law of gravity. Likewise, the remembered final position of a horizontally moving target is displaced to a decreasing extent as one increases the number of surfaces the target “slides” across. This is consistent with the dynamics of friction.

In addition to following the laws of physics, it has been found that such displacements cannot be eliminated by error feedback (Freyd, 1987). Apparently, the dynamics of the environment (i.e., environmental algorithms) have been transferred, via the algorithm of natural selection, into the algorithms of sensory–motor control in such a way that the location of a moving target, just as the “location” of the body in space–time, is contextualized by the target’s “anticipated” location. Further data indicate that these anticipated locations are body-in-space–time relative. Specifically, Reed and Vinson (1996) found that displacements were larger when subjects were told that a vertical, descending line was a “rocket” versus a “church steeple”. However, the finding that displacement occurs, even if what actually happens to the target is inconsistent with the observer’s expectations (i.e., the target “crashes through” a barrier, versus “bouncing off” the barrier; Hubbard, 1994) indicates that while these anticipated locations are body-in-space–time relative, they nonetheless play themselves out according to the rules dictated by the environmental algorithms from which they emerged.

Thus, it appears that the algorithm of natural selection has endowed us with sensori-motor control systems whose dynamics are algorithmically isomorphic with environmental dynamics as well as body-in-space-time dynamics. This algorithmic isomorphy allows organisms to control “anticipatory” flight and pursuit curves toward “anticipated” locations. Vandervert touches upon this isomorphy of algorithms and, in doing so, makes a telling comment about the nature of algorithms:

Of course, the neuro-algorithms that link the fish’s visual perception with the neuroalgorithms that control the fins equally reflect algorithms inherent in the hydrodynamic properties of the water. In sum, algorithms are neither their source system’s nor matter-energy; algorithms are *patterns* of information. (1996, p. 5)

Vandervert’s equating of environmental and neural algorithms with “patterns of information” seems to get to the heart of what J.J. Gibson (1979) meant by his use of the word “information”:

Locomotion and manipulation are neither triggered nor commanded but *controlled*. They are constrained, guided, or steered, and only in this sense are they ruled or governed. And they are controlled not by the brain but by information [algorithms], that is, by seeing oneself in the world. Control lies in the animal-environment system. Control is by the animal *in* its world ... (p. 225)

Gibson’s equating of information with ‘seeing oneself in the world’ casts a different spin on what it is that organisms actually control. For though our language habits lead us to claim that what organisms control is “behavior,” Gibson seems to be claiming that what they control is relationships between what we *call* body and what we *call* environment. In other words, what organisms control is “oneself in the world,” and this is neither body nor environment, but rather, anticipatory body–environment relationships (Jordan, 1997).

This notion that what organisms control is body–environment relationships, and that such control demands anticipatory feels of both the body and the environment, sheds new light on the question of perceptual accuracy. For according to such a notion, there is no need to construct representations of the environment in the nervous system. The sensory–motor control systems of any organism, of which its nervous system is a part, are already mirror images, or “re-presentations” (the hyphen is intended) of the dynamics of the organism-relative environment. The isomorphic coherence between organisms and environments was settled long-ago via the prey–predator scenario and has been passed on, phylogenetically, ever since. Organisms need not “represent.” Rather, what they need do is place themselves in positions that allow their anticipatory phenomenal world to be modulated by environmental information. These variations in the nervous system brought about via such positioning and transduction can be *modeled* as representations, but *theorizing* perception to be the process of constructing such *environmentally-caused representations*, and then claiming perception to be inherently inaccurate or incomplete because these environmentally caused representations cannot be exact replicas of the entire environment, is

to put the cause, or stimulus, of perception in the environment, and simply translate the methodology of psychophysics into a theory of perception. Yes, there does exist a plethora of psychophysical data indicating organisms can transduce only a small portion of information available within the environment. But to describe perception as inaccurate or incomplete because only certain levels of thermodynamic structure (i.e., levels of information) are relevant to an organism's control, is to ignore the fact that these non-immediate levels of information are not open to us until we bring them, via technology, into the realm, or scale, of immediate experience. Once revealed, *these non-immediate levels of information can also be said to be inaccurate because they too represent a particular scale of observation.* In order to describe a given level of information, *one must necessarily ignore other levels of information during the act of measurement, thus all measurements are inherently inaccurate and incomplete.*

These arguments indicate that the notion of perception being inherently inaccurate or incomplete has got it backwards. Perception is not inherently incomplete, it is inherently scale-dependent, as are all measurements. Psychophysical data do not reveal that perception is wrong. They reveal that the informational dynamics which qualify as "environment" for a particular organism are determined by that organism's need to control its relationship to certain aspects of that which lies beyond itself. The algorithms encapsulated in the organizational dynamics of an organism's sensory-motor control systems are exactly the algorithms necessary for that organism to control its propulsion through space-time on anticipatory paths toward anticipated locations. It is this isomorphic relationship among algorithms and their coordination in successful sensory-motor coordinations that truly serves as the yardstick of perceptual accuracy, not the degree of correspondence between the levels of information revealed via physics and immediate experience. Perception is not about "representing," it is about successful control. And it is not inherently incomplete, it is inherently scale-dependent.

Again, the purpose here is not to question the value of psychophysical research. To the contrary, the research on the phantom array, which ultimately led to the theory of perception presented in the present paper, was conducted in accordance with the principles of psychophysics. What is being questioned is the translation of this methodology into a theory of perception. The confusion of scale-dependence and accuracy inherent in representationalist theories is the direct result of putting the cause, or stimulus, for perception *in the environment.* Having done so, it seems appropriate to claim that perception is inherently inaccurate. But the arguments of the present paper support Dewey's claim that if we are to use the words cause or stimulus in reference to organism-environment coordinations at all, they are best used to describe the state of coordination the organism is striving to attain. With stimulus and cause defined in this manner, perception suddenly becomes inherently scale-dependent and *extremely* accurate.

This notion that an organism's need to control its propulsion determines, in a phylogenetically a priori manner, which levels of information (i.e., thermodynamic structures) can be transduced and thus qualify as objects for that organism, leads to the third point by which phantom phenomena challenge representationalist models of

perception – that there exists a real “physical” world of which we experience but appearances.

10. The world of perception

In his book, *Our Knowledge of the External World*, Bertrand Russell (1961) gives an eloquent description of what it means to see a table. It is worth repeating:

A table viewed from one place presents a different appearance from that which it presents from another place. This is the language of common sense, but this language already assumes that there is a real table of which we see the appearances. Let us try to state what is known in terms of sensible objects alone, without any element of hypothesis. We find that as we walk round the table, we perceive a series of gradually changing visible objects. But in speaking of ‘walking round the table,’ we have still retained the hypothesis that there is a single table connected with all the appearances. What we ought to say is that, while we have those muscular and other sensations which make us say we are walking, our visual sensations change in a continuous way, so that, for example, a striking patch of colour is not suddenly replaced by something wholly different, but is replaced by an insensible gradation of slightly different colours with slightly different shapes. This is what we really know by experience, when we have freed our minds from the assumption of permanent ‘things’ with changing appearances. What is really known is a correlation of muscular and other bodily sensations with changes in visual sensations. (p. 84)

While Russell may appear to be taking the long-way-home approach to describing a table experience, what his observation makes clear is that the short-cut provided by common sense (i.e., the belief in the existence of “physical” objects of which we experience “appearances”) is not parsimonious, for it demands the “inferred” existence of such objects. The more parsimonious account is that what we know is “a correlation of muscular and other bodily sensations with changes in visual sensation.” What phantom phenomena add to this idea is the notion that what we know are scale-dependent exafference (environmental information dynamics) and reafference (body-in-space–time information dynamics) as they are contextualized by the organism’s need to control its propulsion along anticipatory trajectories towards anticipated locations.

Within this account then, it is more parsimonious to refer to perception as an act of “information detection” versus one of “representation construction.” The former does not demand the existence of a material world in need of representation, as does the latter. All that is ontologically demanded by the former is the existence some degree of thermodynamic invariance, what one might refer to as “information structures.” The theoretical advantage of the concept “information structure” over “object” is its lack of epistemological connotation. The word “object” connotes a certain degree of a priori givenness – the objects we find in our phenomenal world are material “givens”

which exist outside phenomenology and, therefore, must be “represented” before they can reside within phenomenology. The concept “information structure” however, recognizes that the “objects” we find in our phenomenal world are those invariant aspects of the thermodynamic storm beyond the organism that are relevant to that organism’s control. Aspects of that storm become corpuscularized (i.e., becomes “objects”) within an organism’s field of control (Jordan, 1998). They therefore do not exist as neural representations in the organism’s brain or as material objects in the environment – they exist as invariant thermodynamic information structures that are realized within an organism’s field of control.

This notion, that invariant thermodynamic structures (i.e., information structures) are realized (i.e., are given their objectivity) within an organism’s field of control, is consistent with Niels Bohr’s (1934) description of the “objects” of physics, “In our description of nature the purpose is not to disclose the real essence of phenomena but only to track down as far as possible relations between the multifold aspects of our experience” (p. 18). Within this context, the claim to be able to measure the “physical world” really translates into the ability to manipulate (i.e., control) thermodynamic invariants (i.e., information structures) in such a way as to make certain experiences possible. This notion is also consistent with Henry Stapp’s (1997) quantum-theoretical description the mind–matter relationship:

This description shows how our experiencings become woven into the fabric of the quantum mechanical description of nature: they are the identifiers of events that are the comings into being of these experiencings, and that also act efficaciously upon the mathematical structure that represents the physical aspect of nature. In this new picture of nature the physical aspect constitutes the more subtle aspect of reality: it acts merely as a substrate of *propensities* for experiential events to occur. These experiential events are the more robust basic realities. (p. 177)

What Stapp refers to as “a substrate of propensities,” I have referred to as “information structures,” and it is within an organism’s field of control that such propensities obtain their “objectivity.” Once this is realized, words like “mind” and “matter” come to be seen for what they truly are; crude symbols we utilize in the attempt to communicate to one another the algorithmic order of, or form within, our experiences. In the words of Bertrand Russell,

‘Mind’ and ‘mental’ are merely approximate concepts, giving a convenient shorthand for certain approximate causal laws [algorithms]. In a completed science, the word ‘mind’ and the word ‘matter’ would both disappear, and would be replaced by causal laws [algorithms] concerning events. (1970, p. 292)

11. Conclusions

Perhaps the best trick that evolution ever played on us was the materialization of the world. This perceptual trick, which Vandervert (1990) refers to as the “primordial

constancy,” reflects an evolutionary achievement on the part of organisms that have succeeded in controlling their progress through the information structures beyond themselves; it is a manifestation (i.e., a materialization) of their ability to recognize exafference – as opposed to mere afference. Accordingly, the notion that perceptions are re-presentations of material objects, inferred on the basis of sensory information, has it backwards. Material bodies are the inferences, not the origins, of consciousness. Perceived bodies are not delayed representations of real bodies. The perception of one’s own body, its perceived position in space-time, clearly does not lag behind the body’s own sensory transducers. Phantom limbs and the Phantom Array are experienced within the anticipatory phenomenological context provided by the control of the body–environment relationships. These anticipatory feedforward “feels” allow organisms to propel themselves on anticipatory paths, and it is the control of this propulsion that determines “when” environmental information will be utilized, more so than transfer delays. Further, the spatial memory displacements reported by Hubbard (1995), and the finding that such displacements are consistent with the laws of physics, indicate that the algorithms of environmental dynamics have been rather “accurately” transferred, via natural selection, into the neuromuscular algorithms of sensory–motor control. Thus, while the exafference–reafference distinction resulting from control of body–environment relationships does give rise to the experience of there being something “out there,” *it is the naming of exafference as physical, not the exafference (perception) itself, which qualifies as inference.*

This is the conclusion one comes to when one recasts John Dewey’s “stimulus” (i.e., state of affairs to be maintained) in terms of an anticipatory “feel” of body–environment relationships. Interestingly enough, it seems to be the case that this recasting of the issue is exactly what J.J. Gibson (1979) was attempting to develop in his theory of direct perception. By recognizing that the cause of perception resides, not within the “environment,” but rather, within an organism’s need to locomote through the environment, Gibson was able to develop a theory in which perception was theorized to be an act of information detection (the control of the transduction of environmental algorithms into neuroalgorithms) that reveals affordances (future possibilities of sensory–motor control experienced within the phenomenological context provided by the current intended body–environment relationship). Viewed in this light, current arguments about whether a critical experiment can be designed to test the relative merits of informational and representational models of perception (Hecht, 1996) are misplaced; rather, the question is which model involves a more parsimonious account of the world. The ultimate criterion is Occam’s razor.

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