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COMMENTS

Internally Represented Forces May Be Cognitively Penetrable: Comment on Freyd, Pantzer, and Cheng (1988)

Michael Ranney
Princeton University

Freyd, Pantzer, and Cheng (1988) provided considerable evidence for the proposition that people can represent underlying forces within static scenes. However, they explicitly assumed that their observed memory shifts were the result of *perceptually modular* information processing. For several reasons, I suggest herein that this assumption of cognitive impenetrability is a dubious one. The assumption is challenged by recent empirical findings, some theoretical considerations, and calculations that show that the observed effects are minute when compared with those expected by means of physical forces. Three explanations for the evidence are proposed, including the alternative hypothesis that although people do represent static physical forces, these representations can be almost completely overridden by the conscious intention to remember an object's precise location.

Freyd, Pantzer, and Cheng (1988) clearly demonstrated that when a pictorial element is shown first in equilibrium and then with an applied, nonzero net force, subjects tend to exhibit a memory shift in the direction of that force. In other words, when subjects are asked whether a test display shows the pictured element in the same position as in two previous displays, they are more likely to agree when the element is "moved" (repositioned) in concert with the implied disequilibrium than when it is moved counter to that net force. Freyd et al. cited this memory shift as evidence that people tend to represent the underlying forces of static scenes. They further suggested that such representations may form the basis of our phenomenal, conscious sense of concreteness. This interpretation seems reasonable and is supported by other recent results (see Hubbard & Bharucha, 1988, p. 213, regarding gravity). The foundation for the present discussion, however, stems from a more dubious notion: Freyd et al.'s explicit assumption that the observed effect is the result of encapsulated information processing (see Fodor, 1983), specifically, *perceptual modularity.*

Conscious Beliefs About Static Forces

Freyd et al. (1988) offered two reasons for assuming that their effect was indicative of perceptual modularity, rather than arising from "explicit or conscious knowledge available to more central processing" (p. 406). First, they suggested a discrepancy between their hypothesized, perceptually driven representation of static forces and what they asserted was the apparent lack of conscious representations of such forces. Freyd and her colleagues indicated that the absence of conscious representations can be inferred inasmuch as most untutored people "are surprised to learn that forces operate on static objects" (p. 406). This suggestion is contradicted by current evidence: Minstrell (1982) pointed out, for instance, that most laypeople understand that *gravitational* force operates on static objects (e.g., a book lying on a table); what physics-naive individuals find more difficult to understand are forces that fully *oppose* "active" forces such as gravity, thus keeping an object motionless (e.g., the force directed from the table toward the book, which involves the notion that a barrier can exert a force). Still, recent results show that laypeople can even gain access to some beliefs about these oppositional forces. Clement (1986) reported that 96% of his subjects "believe that a spring pushes up when it is compressed with one's hand" (p. 232)—a static situation comparable with that used by Freyd et al. in their Experiment 4. Although such context-specific responding is often the case in the domain of naive physics (diSessa, 1987; Ranney, 1987/1988; Ranney & Thagard, 1988), untutored people are clearly aware of different sorts of static forces.

In line with considerations about conscious beliefs, one could disconfirm the assumption of perceptual modularity by successfully using one of the following sorts of performance contrasts: (a) comparisons involving individuals who believe that certain static forces hold only for certain classes of objects, or (b) comparisons between groups of subjects who differ in their understanding of the existence or the magnitude of certain static forces. With respect to the first kind of contrast, it seems plausible that particular beliefs about an object's character would modulate the observed memory shift: Consider a case in which a feather is pictured first on a table and

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Correspondence concerning this article should be sent to Michael Ranney, who is now at 4533 Tolman Hall, University of California, Berkeley, California 94720.

then without the table. Because of the feather's drag in air, one might predict an even smaller memory shift for this example than for those observed by Freyd et al., if conscious beliefs truly mediate their effect. More dramatically, if the assumption of perceptual modularity were false and a "levitating" object, such as a cloud (or perhaps a graphemic word), was initially pictured on a pedestal, then later without the pedestal, one would predict no shift at all.

Contrast (b) might involve some expert–novice methodology. If the assumption of perceptual modularity is in error, and if we were to accept Freyd et al.'s (1988) assertion that untutored people do not represent static forces well, then we might expect the memory shifts of expert physicists to be greater than those for physics-naive people. More in general, though, one could argue that if static forces really are represented in a perceptually modular fashion, then *all* subjects should exhibit the memory displacement, regardless of their explicit understanding of mechanics. Unlike Finke, Freyd, and Shyi (1986), unfortunately, Freyd et al. did not provide an analysis of individual differences, and so we are left to wonder about the proportion of subjects who personally exhibited a memory shift in the predicted direction. If stable individual differences could be obtained, however, the modularity assumption would seem less plausible.

The Analogy With Representational Momentum

The second reason used by Freyd et al. (1988) to support their assumption of perceptual modularity is through analogy with prior research on *representational momentum*, in which one's memory for an element's position is shifted in the direction of its implied motion (in analogy to physical momentum): "To the extent that our finding reflects the same sorts of representational properties and constraints as does representational momentum, we assume that it is cognitively impenetrable and that it stems from the perceptual system" (p. 406). The bulk of the present article represents an assessment of this particular argument.

Freyd and Johnson (1987) presented a cogent analysis of the similarity between characteristics of representational momentum and characteristics of physical momentum in such a way that one is compelled to believe that physical momentum is, in some sense, rather accurately "internalized." Freyd et al. (1988) contended that their "representational force" effect (my term) is cognitively impenetrable (Fodor, 1983; Pylyshyn, 1984) because it seems to reflect "the same sorts of properties and constraints as does representational momentum," such as its "rapid and mandatory nature" (p. 406; see also Freyd, 1987). There are reasons, however, to question whether representational force has either of these properties and, indeed, whether representational momentum is itself cognitively impenetrable.

The Speed of Processing

First, we cannot be sure that the observed memory transformation "occurred in the 250-ms retention interval between the to-be-remembered display and the test display" (Freyd et al., 1988, p. 406). It seems possible that the memory shift is not an on-line process but, rather, involves postperceptual processing between the test display and a subject's response. This proposition is in concert with Hubbard and Bharucha's (1988) suggestion that "memory displacements for horizontal and vertical apparent motion can persist for longer periods of time" (p. 220), even beyond 2 s.

Modularity and the Analogy

Hubbard and Bharucha's (1988) results also challenged the analogical link between representational momentum and representational force by indicating that the former is *not* perceptually modular. In their experiments, subjects were asked to position a cross hair over the point at which a linearly moving target unexpectedly vanished from a viewing screen. Although Hubbard and Bharucha found memory displacements compatible with the notion of representational momentum, they also found that the magnitude and direction of such displacements could be mediated by conscious knowledge of an impending change in direction (e.g., due to an imminent bounce off a barrier). In contrast to the perceptual modularity assumption of Freyd and her colleagues, Hubbard and Bharucha wrote that such displacement "seems to involve knowledge of the future position of the moving target, implicating a high-level cognitive mechanism that predicts the future position of a moving target on the basis of knowledge of its previous pattern of behavior" (p. 220).

Given these findings, one might also try to disconfirm the perceptual modularity assumption for representational force by introducing verbal instructions that negate forces implied by Freyd et al.'s (1988) displays. One might tell subjects, for example, that for the box-on-spring display used in Experiment 4, both the box and the spring are floating on a spacecraft in zero gravity and merely happen to be juxtaposed. If this manipulation of subjects' conscious beliefs eliminates the representational force effect, we might conclude that it is *not* perceptually modular.

A Diminutive Effect

Freyd et al. (1988) suggested that their effect is mandatory because their subjects could not avoid the memory transformations brought about by the implied net force. To the contrary, I argue that their subjects did a reasonably good job of ignoring the introduced disequilibrium, keeping the memory shift to a small fraction of what one would expect if the effect were the result of mandatory and cognitively impenetrable information processing. This argument follows directly from the data that Freyd et al. reported: In particular, the results indicate that the subjects' memory shifts do *not* accurately reflect the physical forces implied by the experimental materials, which suggests that their representations were widely penetrated by the conscious desire to remember the correct position of a pictorial element.

Consider Experiment 1, in which a plant was pictorially presented in three displays. In the first display, the plant was shown supported and in equilibrium. In the second display, the plant was exhibited without any support, so that the subject would get the sense that its gravitationally driven descent began. Then, after a 250-ms delay, a test display was provided. In keeping with prior research on representational momentum (Freyd & Johnson, 1987), we would expect this "retention interval" to lead subjects to respond as if the unsupported plant had been dropping for one quarter of a second. If people accurately internalized the gravitational acceleration due to gravity, they would have the sense that the plant fell 30.6 cm (about 1 foot), according to the following formula, found in any introductory physics text:

$$d = \tfrac{1}{2}gt^2, \quad (1)$$

where d is the distance a falling body travels over t seconds because of gravitational acceleration g (9.8 m/s^2).

Thus if the analogy between representational momentum and representational force were an apt one, we would expect that people would yield an estimated memory shift of approximately 30.6 cm, once corrected to the scale of the display screen. However, the data and stimuli provided by Freyd et al. (1988) show that the observed memory shifts were only a small fraction of this prediction. From information provided by their Experiment 1, I calculate that their subjects' average shift value was only about 0.04 cm on the display screen, which translates to about 1.21 cm of vertical distance in the physical world.[1] In essence, when the shift value is scaled to the appropriate physical dimensions for the objects pictured (i.e., the plant and the window), the plant "dropped" only about 4% of the distance that a real plant would fall. By transforming Equation 1, one can learn that a real plant would have covered that distance in about a fifth as much time as that implied by the 250-ms retention interval. One can also transform Equation 1 to discover that g', the "internalized acceleration due to gravity," is only 0.38 m/s^2, about 4% of the true gravitational acceleration.

The value for internalized acceleration from Freyd et al.'s (1988) Experiment 3 is even smaller than that for Experiment 1. The scale is trickier; however, assuming that the lock used in Experiment 3 is approximately 9 "real" cm in height, g' is found to be a mere 0.3% of g. (At this rate of 0.03 m/s^2, it would take more than 10 s for the lock to fall 5 feet!) Experiment 4 provided no scaling cues and involved a *nongravitational* implicit force (by means of a coiled spring), and so only the acceleration with respect to the display screen can be calculated. Still, this acceleration was also very small (a = 0.02 m/s^2) when considered with respect to forces exerted by common springs.

Three Explanations

These calculations merely serve to show that, in general, people do not accurately internalize representational force. With respect to the present question of perceptual modularity, there seem to be three explanations for this finding. First, in concert with Freyd et al.'s (1988) modularity assumption, one could propose that an obligatory, yet diminutive representational force might be perceived; that is, the observed effect may be the result of mandatory and encapsulated processing that is merely a weak analogue to true physical forces. For instance, this effect might well be a linear function of the retention interval (e.g., velocity v = 0.05 m/s, with $d = vt$), in contrast to the nonlinear function of true, accelerative forces. Such a linear relation, however, would be more suggestive of an internalized momentum (p = Mass × v) rather than an internalized force (F = Mass × a). On the other hand, the effect might follow a nonlinear relation that is merely quite small in magnitude (e.g., the internalized gravitational acceleration estimates of 0.38 m/s^2 and 0.03 m/s^2). Of course, either of these kinds of internally diluted forces could be due to dynamic limits on our ability to transform images (cf. Freyd & Johnson, 1987), and so this explanation, by itself, does not weigh against the assumption of modularity. The same cannot be said for the remaining explanations (or for many of the previous considerations).

A second explanation for this dilution would parallel that used by Freyd and Johnson (1987, pp. 263–265) to model their representational momentum results; that is, one might postulate an independent memory-averaging process that accompanies, opposes, and eventually dominates the representational-force process. However, the memory averaging that they suggested for representational momentum varies linearly with the retention interval and so could not yield a reasonable net effect (in the absence of a drag coefficient). Consider a limiting case, in which the retention interval is rather long: A mandatory, nonlinear internalization of gravitational force would indicate that the padlock pictured in Freyd et al.'s (1988) Experiment 3 had accelerated completely out of the display screen so that no linear memory-averaging process would result in a "same" response for any test display that included the lock within the display screen. For this case, if an internal-force process were modular with respect to such a memory-averaging process, a subject would respond "same" only if there were no stimulus in the test display! (For the padlock, this would be true after an interstimulus interval of less than 2 s, given a g' of 0.03 m/s^2 and a mild memory-averaging process.) Hence this explanation of the observed effect seems lacking.

Last, there exists the simple possibility that the observed dilution indicates considerable *nonmodularity* in the information processing that underlies Freyd et al.'s (1988) effect. This hypothesis acknowledges their main conclusion, that people can represent the underlying forces of static scenes,

[1] These values were calculated in the following way: The average memory shift for Experiment 1 was estimated to be +0.283 of the distance to the lowered position, the same as that discerned by Freyd, Pantzer, and Cheng (1988) for Experiment 3. This estimate seemed reasonable, given the percentages of "same" responses for the −1, 0, and +1 distractor positions: 37%, 90%, and 57% from Experiment 1 (and in comparison with the values of about 65%, 90%, and 80%, as extracted from Experiment 3's Figure 5). The scale was estimated to be 30.5 cm (1 foot) for each centimeter on the display screen (i.e., the plant and its hanger was estimated to be 2.35 feet in height, and the window, about 4 feet in height). Given this scale and a 250-ms retention interval, true gravitational acceleration would yield a memory shift of +7.143—more than 25 times the present estimate of +0.283.

but it postulates that these representations can be almost completely overridden by the conscious desire to remember an object's precise location (cf. Finke et al.'s 1986 *cognitive resistance*). In this way, the relative absence of perceptual modularity for representational force explains its remarkable diminution. This hypothesis may be tailored or discarded once researchers observe how the effect varies as a function of retention interval (or expertise, or the character of the target element, or the manipulation of subjects' beliefs, as recommended earlier). However, the possibility that people can override representational force is supported by two other findings, heretofore unmentioned, that further emphasize the small size of the "representational force" effect: (a) that the accuracy with which Freyd et al.'s subjects remembered a target's precise position was almost 90%, which was at least as high as the accuracy for control conditions involving no disequilibration (see especially Experiments 1 through 3), and (b) that the observed memory shifts were all theoretical, as none of the reported experiments yielded a qualitative *recorded shift* (i.e., no display in which the target was shifted ever elicited more "same" responses than the display that showed the target in its unchanged position).[2]

Conclusions

Although Freyd et al. (1988) convincingly showed that representations of physical force tend to interfere with our ability to accurately remember the location of pictured objects, both of their reasons for assuming that the underlying process is perceptually modular are questionable. First, the divorce between belief-driven and perceptually driven representations of static forces is still unproven, even for physics-naive people. Second, the analogy between representational momentum and representational force, which motivates the suggestion that the latter is "also" rapid and mandatory, encounters three difficulties: (a) Recent findings have called into question the *source* of the analogy (i.e., the perceptual modularity of representational momentum); (b) there is insufficient evidence to believe that the observed effect is due to on-line processing; and (c) the very small magnitude of the observed effect, in relation to analogous physical forces, indicates that conscious constraints may well penetrate the computation of representational force. Fortunately, as the present set of ambiguities seem to involve empirically tractable questions, this article suggests some manipulations and analyses that may lead to their resolution.

[2] Freyd, Pantzer, and Cheng (1988) pointed out that a recorded shift would probably manifest itself with the use of even more finely grained distractor positions (p. 401). Still, the absence of a single recorded shift over many experiments highlights the diminutive nature of the memory shift.

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