Final exhibit graphic

third presented suggestions ("Try this") and four explanations for what might be happening, challenging visitors to consider which explanation seemed to best fit the results of the races. We tried to prevent this last graphic from having the feel of a multiple-choice test—but that, unfortunately, seemed to be how visitors saw it.

Interestingly, we found that the graphic with no explanation seemed best at engaging visitors physically and intellectually. Visitors who saw that graphic ran more races and talked more about what might be causing the wheels to roll faster or slower than did visitors who saw other versions. However, there was anecdotal evidence that some visitors felt frustrated by the lack of explanation. For instance, one visitor, after being very engaged with the exhibit, looked directly into the camera and said into one of the microphones, "You should give us an explanation!" The final version of the exhibit includes a more traditional graphic containing both suggestions and an explanation. We have found that, even when visitors read the explanation, they still run races in order to test it. (In an effort to avoid adopting an authoritative voice in the graphic, however, we used a casual tone in the "What's going on?" explanation: "When weight is located far from the center of the wheel, the wheel is harder to get rolling. (A physicist would say it has more rotational inertia.)"

Visitor Behavior

Because the exhibit is meant to be used as a race, visitors seem to know intuitively how to use it. Although the holding time is not the longest of our *APE* exhibits (mean = 2.2 minutes; longest = 7.9 minutes), visitors are very engaged physically and intellectually. After running a race or two, adult visitors often begin systematic investigations, creating hypotheses and testing them. With the original metal wheels, the exhibit supported the correct conclusion and two alternates, namely, that the differences in speed were due to weight or to air resistance. With the current wheels, the main possibility that visitors tend to test is whether the weight or weight distribution is the key factor in determining speed.

Parents tend to co-investigate with their children. Once the parents have figured out that the distribution of weight is the key variable, they often explain it to their children or race specific wheels to demonstrate it. (On some occasions, the children figure it out first and try to convince their parents!)

We were concerned that in removing air resistance as a possible factor in the race we would overly limit the investigation, turning *Downhill Race* into something more like a planned discovery exhibit and leading visitors to run one or two races, read the explanation, and consider themselves done. Happily, this is not the case: often, visitors run many races—comparing various wheels, sliding the weights on the adjustable wheels, and testing out their ideas. As mentioned, even when visitors read the explanation in the graphic, they often continue to run races to confirm it.

Younger visitors also use the exhibit as a race, watching the wheels roll the complete length of the track until there is a winner. Without adult supervision, they sometimes push the wheels to speed them up, trying to help their chosen wheel win the race. (They also sometimes push the wheels violently up and down the track, crashing them into each other. Over the course of two years, the edges of the metal wheels became severely mushroomed.)

Variations

The tracks are tilted at nominally 5 degrees from the horizontal. This is close to the maximum angle possible before the axles slip on the track rather than roll. At this angle, the wheels take between 15 and 20 seconds to roll the length of the track; this seems to be a good length of time for building dramatic tension. It would be possible to use a shorter track with much less slope and have the wheels take about the same amount of time to reach the end, but their rotational speed would be much less, which might change the feel of the exhibit.

Reflections on What Works

It seems to me that there are three aspects of this exhibit that make it work well. First, visitors intuitively understand what a race is, so they immediately start using the exhibit by choosing two wheels and placing them on the track. Second, visitors come to the exhibit with expectations about how weight affects the speed at which things move. Luckily, these expectations are often wrong, setting visitors up for a nice surprise that motivates them to try more races. The key idea isn't too difficult, though, and most visitors figure out what's happening or read the explanation. Third, the activity of choosing two wheels before racing them forces visitors to make an implicit prediction about which will go faster. This might be critically important for engaging visitors in figuring out the key variable that affects wheel speed. We have found in other exhibits that visitors often simply assimilate surprising results as if they had always expected them. (Psychologists call this effect the *hindsight bias*.) If visitors did not have to make predictions—even unconscious ones—they might not be motivated by the results to try to figure out what's happening.

Construction

The exhibit consists of six wheels, two steel tracks, and a plywood support structure. The wheels are made of acetyl plastic with cylindrical brass weights attached with screws. There are four wheels with fixed weights, two with small weights, and two with larger weights. There are also two wheels with adjustable weights that can be moved from the center to near the edge.

The wheel axles are made of hardened and ground tool steel (0-1). The use of hardened steel makes the axles less susceptible to damage when dropped on the track or on the floor. The axles are short with a fairly large diameter (3/4-inch diameter by 7/8-inch long on each side), making them strong and resistant to bending.

The axles are rough machined to approximately .010 inch oversize, heat treated to Rockwell C60–65, and then ground between centers to finished size. The axles are pressed into the wheels using a very tight (.007-inch) interference fit. The wheels are then balanced between centers. After balancing, the ends of the axles are removed using an abrasive saw and the ends finished smooth.

Each track is made of two precision-ground hardened 1-inch-diameter steel rods. There are two tracks (four rods total) in the exhibit. Because the wheel axles are tapered, the spacing between the rods cannot vary along the length of the track without influencing the speed of the wheels. The rods are very rigid (because of their diameter) and are tightly held in precision-machined aluminum blocks on each end of the exhibit. These blocks also attach the rods to the support structure. To help visitors get the wheels started straight and in line with each other, plastic guides, or nests, are provided at the top end of each track.

The exhibit is constructed with plywood ends and a structural plywood shelf.


Visitors running races

The tracks are connected to the plywood by heavy aluminum way mounts, which clamp to the rods and are in turn screwed to the plywood ends. Because the 1-inch-diameter track rods are so rigid and strong, they also serve as the exhibit's primary structural unit, stabilizing the plywood end supports. The rods that form the tracks are fairly long (8 feet), so the exhibit has some rotational limberness. This means that it always sits with all four corners on the floor, even if the floor is a bit uneven (as ours certainly is). The design of the exhibit followed from the decision to use the readily available rods for the tracks. A rack at the bottom of the track lets us store wheels not in use.