

The Gyroscope Is Two Orders Too Small to Explain Why a Bicycle Does Not Fall

— The restoring torque required is **68.3765** N·m; the front wheel's gyroscopic torque is **1.2750** N·m — A gap of **53.6286** — The two become equal at **965** km/h — [Paper 359]

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— *From thinking to syncing.* —

Abstract

A moving bicycle is said to stay up because of the gyroscopic effect of its wheels. This paper asks whether that explanation is the right order of magnitude—the answer is that it is not. No new mathematical theorem and no new law is claimed. First, the gravitational torque on an 80 kg bicycle-and-rider leaning 5 degrees is **68.3765** N·m (Section 2). Second, this is the core of the paper. The front wheel's gyroscopic torque is only **1.2750** N·m, a gap of **53.6286** (Section 2). Third, quadrupling the speed brings it only to 5.1000 N·m (Section 2). Fourth, the two become equal at **268.14** m/s, that is **965** km/h (Section 2). Fifth, what remains is steering: a 5 degree lean is balanced by a turn of radius **29.1385** m (Section 3). Sixth, the separator is whether a mechanism is individually necessary, not whether it acts at all (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed—the gyroscopic effect, caster trail, and the inverted pendulum are all standard. We do not build bicycle dynamics—the four-degree-of-freedom linearised model and its eigenvalue analysis (weave, capsize) are not entered. They are named and no more. We prove no self-stability—the speed range over which a bicycle is self-stable is not computed. What is computed here is the size of torques. We perform no experiment—no measurement on a real machine is made. The numbers are on parameters stated explicitly. Control is not treated—the rider’s reflexes and learning are not the subject. Tyres are not treated—contact patch deformation, slip angle, and toe are not the subject. Relation to earlier papers: Paper 357 showed maximum power and maximum efficiency to be different points—there there were two objectives; here there are two explanations. Paper 356 showed quantities of the same dimension to be different quantities—here two torques of the same dimension are compared in size. Paper 300 showed whether two things share a root is decidable—by that test, gyroscopic restoration and steering restoration have distinct roots. Paper 353 showed a claim turning false when its condition is dropped—confusing “it acts” with “it suffices” is the same error. What is added is giving both torques as numbers under one set of conditions, showing the ratio to be 53.6286, solving backwards for the 268.14 m/s at which they are equal, giving the time available from the inverted-pendulum time constant, and putting the separator on individual necessity.

1. Notation and the Question

Setting: Treat the front wheel as a thin ring of mass $m_w = 1.5$ kg and radius $r_w = 0.34$ m.

$$I_w = m_w r_w^2 = 0.1734 \text{ kg m}^2, \quad T_{\text{gyro}} = I_w \omega \Omega, \quad T_{\text{grav}} = M g h \sin \theta$$

Take bicycle and rider together as $M = 80$ kg with centre of mass at $h = 1.0$ m.

Observation 1.1

Two explanations are commonly heard. The gyroscopic effect of the wheels, and restoration by caster (trail)—both are real effects.

Observation 1.2

This paper denies neither. What is asked is only the size—because “it acts” and “it suffices” are different things.

Observation 1.3

Treating the wheel as a ring is an upper estimate. A real wheel has spokes and a smaller moment of inertia —so the comparison is made with the gyroscopic side favoured.

Question: Is the gyroscopic effect enough to arrest a fall?

2. Two Orders Short

Calculation 2.1: Both torques under one set of conditions (computed in this paper).

Quantity	Value
Front-wheel moment of inertia I_w	0.1734 kg m ²
Wheel angular speed ω at 5.0 m/s	14.7059 rad/s
Steering rate Ω	0.5 rad/s
Gyroscopic torque T_{gyro}	1.2750 N m
Gravitational torque at 5 degrees T_{grav}	68.3765 N m
Ratio	53.6286

Observation 2.2

This is the core of the paper. A factor of 53.6286 is not “slightly short”—it is nearly two orders of magnitude. The gyroscopic effect cannot be the main actor.

Observation 2.3

Speed does not close the gap. At 20 m/s (72 km/h) the gyroscopic torque is 5.1000 N·m—still far from 68.3765 N·m.

Observation 2.4

The equalising speed can be solved for. $T_{\text{gyro}} = T_{\text{grav}}$ at $v = \mathbf{268.14}$ m/s—that is **965** km/h. It is no longer a bicycle.

Observation 2.5

Every estimate was taken in the gyroscope's favour. Wheel as a ring, a standard rather than a light wheel, and a steering rate that is not small—and still this is the gap.

Observation 2.6

Care is needed here. The claim is not that the gyroscopic effect is absent— $1.2750 \text{ N}\cdot\text{m}$ is real. The claim is that by itself it is not an explanation.

3. What Remains Is Steering

Calculation 3.1: Times from the inverted pendulum, and the balancing turn (computed in this paper).

Quantity	Value
Time constant $\sqrt{h/g}$	0.3193 s
Time to fall from 1 degree to 10 degrees	0.9558 s
Turn radius balancing a 5 degree lean at 5 m/s	29.1385 m

Observation 3.2

There is about a second. 0.9558 s to fall from **1** degree to **10**—long by the standard of human reaction time. So the rider gets there in time.

Observation 3.3

The way to recover is to bring the contact patch back under the centre of mass. Steer into the fall—a 5 degree lean is exactly balanced by a turn of radius 29.1385 m.

Observation 3.4

This steering torque is the same order as the gravitational one. It comes straight out of the balance $\tan \theta = v^2 / (Rg)$ —it does not pass through a small intermediate quantity as the gyroscopic route does.

Observation 3.5

Distinct roots by the criterion of Paper 300. Gyroscopic restoration comes from conservation of angular momentum, steering restoration from the geometry of balance—two mechanisms explaining one fact, with different roots.

4. “Acts” Is Not “Necessary”

Observation 4.1

The literature shows neither gyroscope nor trail to be individually necessary. A design cancelling both has been made self-stable—this paper does not reproduce that experiment. It is cited and no more.

Observation 4.2

What this paper can show independently is a size. The ratio 53.6286—it states “not enough by itself” in orders of magnitude. It is an agreement reached from a different road than the literature’s.

Observation 4.3

The two claims have different strengths. “Two orders too small” is carried by the computation here —“individually unnecessary” is carried by the literature. They are not mixed.

Observation 4.4

To be stated honestly——this paper does not fully answer “then what holds it up”.What is shown is that steering remains as the only candidate of the right order——self-stability itself is a four-degree-of-freedom eigenvalue problem and does not reduce to a single mechanism.

5. The Separator: Individually Necessary?

Observation 5.1

The separator——not whether a mechanism acts, but whether it suffices alone, and further whether it is necessary alone.

Question	Gyroscopic effect	Steering	Carried by
Does it act	yes (1.2750 N m)	yes	this paper
Does it suffice alone	no (1/53.6286)	right order	this paper
Is it necessary alone	no	no	the literature

Observation 5.2

The three rows are different questions.A “yes” in the first does not settle the second——everyday explanations collapse all three into one.

Observation 5.3

The rightmost column is the discipline of this paper.Write, row by row, what carries which claim——different provenance means different strength.

Observation 5.4

The separator can be moved. Make the wheel extremely heavy and the gyroscopic torque grows—but bringing the ratio 53.6286 to 1 needs 53.6286 times the moment of inertia, a front wheel of some 80 kg. At that point the vehicle is not a bicycle.

Observation 5.5

To be stated honestly—68.3765 N·m and the ratio 53.6286 are values on parameters stated explicitly. Another bicycle gives other numbers—what does not move is the structure: gyroscopic torque scales with speed and gravitational torque does not depend on it.

Observation 5.6

One last thing—“is the effect real” and “does the effect explain it” are different questions. The gyroscopic effect is real, and it is not enough—stop at confirming that something is real and you are satisfied without ever having looked at the order of magnitude.

6. The Census and the Close

1. $I_w = 0.1734 \text{ kg m}^2$ (Calculation 2.1): an upper estimate, as a ring.
2. $T_{\text{gyro}} = 1.2750 \text{ N}\cdot\text{m}$ (Calculation 2.1): 5 m/s, steering 0.5 rad/s.
3. $T_{\text{grav}} = 68.3765 \text{ N}\cdot\text{m}$ (Calculation 2.1): 80 kg, 5 degree lean.
4. Ratio 53.6286 (Observation 2.2): nearly two orders.
5. Only 5.1000 N·m at 20 m/s (Observation 2.3): speed does not close it.
6. Equal at 268.14 m/s (Observation 2.4): 965 km/h.
7. Time constant 0.3193 s (Calculation 3.1): inverted pendulum, $h = 1 \text{ m}$.
8. 0.9558 s from 1 to 10 degrees (Calculation 3.1): long enough for a person.
9. A 5 degree lean balances at radius 29.1385 m (Calculation 3.1): steering is the right order.
10. Three different questions (Observation 5.2): acts / suffices / necessary.

Closing: A moving bicycle is said to stay up because of the gyroscopic effect of its wheels—and the gyroscopic effect is certainly real. But it is two orders too small—treating the front wheel as a thin ring (which overestimates

its moment of inertia), riding at 5 m/s and steering at 0.5 rad/s gives a gyroscopic torque of **1.2750 N·m**. The gravitational torque on an 80 kg bicycle-and-rider with its centre of mass at 1.0 m, leaning 5 degrees, is **68.3765 N·m**. The ratio is **53.6286** — not “slightly short” but nearly two orders of magnitude. Speed does not close the gap — at 20 m/s (72 km/h) the gyroscopic torque reaches only 5.1000 N·m, and the two become equal at $v = 268.14$ m/s, that is **965 km/h**. It is no longer a bicycle. What remains is steering — as an inverted pendulum the time constant is 0.3193 s, and falling from 1 degree to 10 takes 0.9558 s, long by the standard of human reaction time. So the rider gets there in time. Recovery means bringing the contact patch back under the centre of mass — steering into the fall — and a 5 degree lean is exactly balanced by a turn of radius 29.1385 m. That restoration comes straight out of $\tan \theta = v^2 / (Rg)$, so it is the same order as the gravitational torque. But the strengths of the claims must not be mixed — “two orders too small” is carried by the computation here; “individually unnecessary” is carried by the literature. A design cancelling both gyroscope and trail has been made self-stable, but this paper does not reproduce that experiment. What this paper says independently is the ratio 53.6286, reaching the same conclusion by a different road. One thing separates them — not whether a mechanism acts, but whether it suffices alone, and further whether it is necessary alone. The three are different questions, and a “yes” to the first does not settle the second. Bringing the ratio to 1 would need 53.6286 times the moment of inertia — a front wheel of some 80 kg — and at that point the vehicle is not a bicycle. To be said honestly — this paper does not fully answer “then what holds it up”. What is shown is that steering remains as the only candidate of the right order. Self-stability itself is a four-degree-of-freedom eigenvalue problem and does not reduce to a single mechanism. One last thing — “is the effect real” and “does the effect explain it” are different questions. The gyroscopic effect is real, and it is not enough. Stop at confirming that something is real and you are satisfied without ever having looked at the order of magnitude.

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