If the Rubber Hand Illusion Is an Illusion, Then Car Driving Is an Illusion Too

The Illusion Evaporates the Moment the True Mechanism of Action–Perception Coupling Is Understood




Caught In A Line
The explanatory model of all motoric movement actions

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Abstract

If the Rubber Hand Illusion (RHI) is interpreted as an "illusion", then the same logic would force us to classify everyday motor actions—such as car driving—as illusions as well. Both phenomena expose the same pre-actional uncoupled state in which the visual and proprioceptive foci remain temporarily autonomous because no motor-causal coupling has yet occurred.

The explanatory model of the motoric movement action shows that bodily ownership and agency arise only when an internally generated proprioceptive configuration is causally verified against an externally specified action trajectory shape (ATS). This verification is performed by a rapid hyper-feedback loop immediately before movement. When this loop has not yet been engaged, the system cannot determine which external consequence "belongs" to the organism.

Car driving reveals this mechanism with perfect clarity. In an automatic vehicle, if one is unsure whether the car is in drive or reverse, the visual and proprioceptive foci remain uncoupled until a minimal motor action produces an observable external consequence. Only when the hyper-feedback loop links internal intention to external displacement does the driver establish causal ownership of the vehicle's motion. Similarly, in a toy racetrack with two stationary cars, the controller's first arbitrary movements are used to discover which car responds. The moment of uncertainty—before any causal link is verified—is structurally identical to the RHI. It is not an illusion; it is the natural pre-actional state in which coupling has not yet occurred.

From this perspective, the RHI does not show that the brain can be deceived about the body. Instead, it reveals the same premotor verification mechanism that governs all motor actions: the system must first determine *which external effect corresponds to its own internal movement*. The RHI is therefore not a perceptual error, but the laboratory exposure of an otherwise hidden phase of motor architecture—one that is equally present in driving, tool use, and every form of sensorimotor control.

Keywords: *Rubber Hand Illusion; action trajectory shape; motoric movement action; hyper-feedback coupling; dual perceptual foci; bodily ownership; egocentric motor control; proprioception; visual–proprioceptive integration; latent–manifest architecture.*

Introduction

The Rubber Hand Illusion (RHI) is widely presented as evidence that the brain can be misled about which limb belongs to the body. When synchronous visual and tactile signals are applied to a hidden real hand and a visible rubber hand, many participants report that the artificial hand feels like their own. This report has been treated as a perceptual illusion—a failure of multisensory integration in which vision overrides proprioception. Yet, despite the influence of this interpretation, the RHI has never been explained at a mechanistic level. Why the phenomenon requires passivity, why it collapses under active movement, and why proprioceptive drift does not reliably track ownership have all remained unresolved.

The explanatory model of the motoric movement action (2016) provides an alternative account. It shows that bodily ownership is not a sensory judgment but the result of a premotor coupling mechanism that precedes every voluntary action. Visual and proprioceptive information belong to autonomous and incompatible perceptual domains. They can only be unified when an internally generated proprioceptive configuration is causally verified against an externally specified action trajectory shape (ATS). This verification is performed by a rapid hyper-feedback loop immediately before movement, which tests whether internal changes produce the correct external displacement of the body or tool. Ownership and agency emerge at this precise coupling moment—not from sensory fusion.

This mechanism is not limited to body perception; it governs all motor actions. Everyday car driving makes this clear. In an automatic vehicle, if one is briefly unsure whether the gear is in “Drive” or “Reverse,” no amount of looking or sensing can establish the answer. Only a minimal motor action—an internal movement producing an external effect—can reveal the causal relationship. Until that moment, the system remains in a pre-actional uncoupled state, unable to determine which external consequence belongs to the driver. Once a causal match between internal intention and external motion is confirmed, ownership of the vehicle’s movement is instantly established.

A structurally identical state appears in a toy racetrack with two stationary cars. When the controller is activated, the first arbitrary movement is not part of the actual task; its purpose is diagnostic. It determines which car responds. Before that coupling, the system cannot know which external object is “mine.” This moment of causal uncertainty is mechanistically equivalent to the state exploited in the RHI. It is not an illusion but an uncoupled configuration in which the hyper-feedback mechanism has not yet been engaged.

Seen from this perspective, the RHI does not demonstrate that the brain can be fooled about its own body. Instead, it reveals the same premotor coupling mechanism that governs grasping, driving, tool use, and every form of sensorimotor control. The so-called illusion arises not because perception is deceived, but because the critical step that normally binds internal movement to external consequence has been deliberately suppressed. If this state is to be classified as an “illusion,” then the brief uncertainty during car driving or during toy-car control would have to be classified as illusions as well—an untenable conclusion.

The present article develops this argument in full, showing that the RHI is best understood as the deliberate laboratory isolation of a universal pre-actional uncoupled phase in motor control. Far from being a perceptual error, it provides a unique window into the fundamental mechanism by which the two autonomous perceptual foci—visual and proprioceptive—become causally coupled in all voluntary action.

Part 1
The perception of action trajectory shapes

The explanatory model of the motoric movement action demonstrates convincingly that within every conceivable action, a perceptual image of a latent action trajectory shape is always created first, before the action can even be executed. It shows this with scientific evidence and an abundance of logical reasoning.

A true novelty within this explanation concerns that the end of the trajectory shape is evaluated within the preceding *tactical movement action* (TMA), but that it is equally essential to take the bridging process into account. This bridging process constitutes the very essence during the actual execution, the *factual movement action* (FMA), and that has been completely overlooked by science.

The explanation shows that precisely this egocentric process requires the double and reciprocal mediation of the cortical streams, and it demonstrates that without a perceptual image of an action trajectory shape, nothing could ever be executed — and that it always happens implicitly, even when one consciously tries to deny the existence of the action trajectory shape.

In this part, a various range of motoric actions become clarified, all of which display the aforementioned universal principles and the multitude of perceptual processes that are inevitably coupled to them. The explanation proceeds from the example of grasping a coffee cup toward motoric actions involving one's own body. Within that discussion, it becomes evident that *self-tickling* is no exception to these universal principles, and that we will never be able to tickle ourselves.

A. Motor actions with an External Environmental Object

To fully unravel the phenomenon of action trajectory shapes, motoric actions are divided into two groups: 1. Actions involving an external environmental object, and 2. Actions involving one's own body part as the environmental object.

It will be shown that the perceptual processes regarding the creation and execution of the action trajectory shapes do not differ within this twofold division. All actions can only be executed if a perceptual image of a latent action trajectory shape has been created. Without such a line, an action cannot begin.

This simultaneously touches upon a *novum* that emerges within its explanation: the action trajectory shape indeed has a clear end goal, but it also concerns an autonomous bridging process of all places *P* of the end-effector between the starting point and the endpoint of the action trajectory shape. This fact is equally essential within our perceptual processes and has never before been recognized within science.

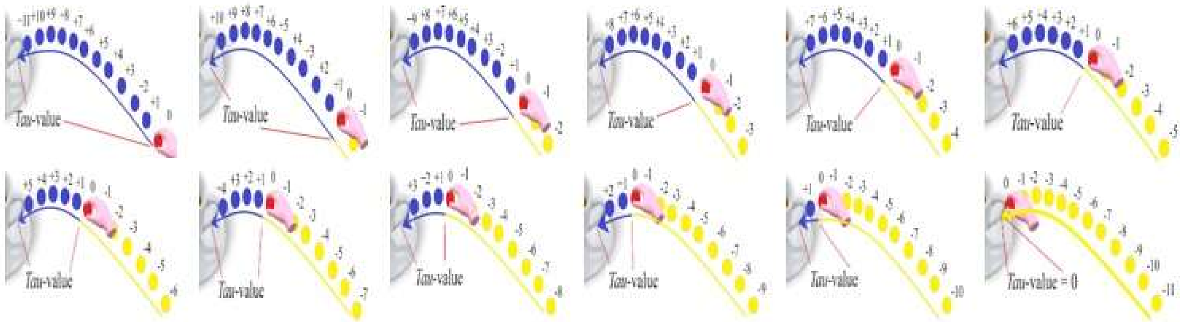
Furthermore, it demonstrates that in the execution of actions directed toward one's own body, proprioceptive perception can be far more dominant and is even capable of executing actions autonomously. Which also reveals the *novum* that proprioceptive perception will always remain present in a hybrid form, even when the action can be performed through visual perception.

1. Grasping a Coffee Cup[1]

The explanatory model of the motoric movement action shows, with scientific evidence[2], that before the actual execution of grasping can take place, a latent action trajectory shape is always created between the current position of the fingertips and the cup. It thereby provides a final answer to the entire scientific issue concerning *predictive coding*, *predictive processing*, and *prediction errors*, and shows with the formation of this action trajectory how grasping is afforded and how, during its actual execution, it is mediated online.

It is furthermore demonstrated that we can only execute the exclusively external line from the fingertips by means of internal bodily movements[3]. The outer surface of the fingertips consists of living cells, yet they can't be moved there. The movements belong to two entirely separated worlds, therefore concerning two foci, and thus the internal and external perception are completely autonomous.

When grasping a coffee cup, the main purpose therefore concerns the construction of the action trajectory shape as part of the tactical movement action (TMA) and the actual execution of the external action trajectory shape during the factual movement action (FMA) — as that compels the phenomenon that actually reaches the cup — and therefore the primary focus must be directed toward it. The internal bodily movements are only important for realizing this main goal and therefore concern the secondary focus, which must accordingly be directed toward that action trajectory shape.



Illustrations: *From any random position P of the fingertips, prior to factually grasping a coffee cup, a perceptual image is constructed of a successful latent action trajectory shape. Within that tactical processing — the tactical movement action (TMA) — the eventual grasping is considered, but, equally essential, it is determined whether the bridging process can take place through a continuous sequence of positions of the fingertips. This represents the very essence of the great omission within scientific thinking. The tactical deliberation encompasses the environmental object but the factual execution of that task in its ecological and evolutionary essence concerns the reduction of the number of places between the fingertips and the coffee cup. The perspective within this motor action must therefore be regarded out of the fingertips, and not out of the coffee cup.*

[1] https://www.explanatorymodel.nl/common-daily-actions/grasping
[2] https://www.explanatorymodel.nl/common-daily-actions/grasping/within-the-grasping-of-a-coffee-cup-we-always-first-construct-a-perceptual-image-of-a-latent-action-trajectory-shape-out-of-the-perspective-of-the-fingertips-the-scientific-evidence
[3] https://www.explanatorymodel.nl/common-daily-actions/grasping/grasping-requires-a-compelling-collaboration-between-an-internal-and-an-external-focus

Due to the two autonomous foci, a peculiar figure arises during the act of grasping a coffee cup, just as in every other motoric action. Solely the action trajectory shape — consisting of future fingertip positions — will perform the very essence of the task, yet it can do nothing by itself. It can only be executed by a completely different, autonomous, internal movement.
The explanatory model of the motoric movement action reveals, with this given, the most economical system ever conceivable. It shows that we are able to start moving the fingertips from any random position, to stop them at any moment, to change their path, or otherwise. It shows that with a minimum of means a maximum output can be achieved.

However, there is a price to be paid for this ultimately economical system. Because two autonomous foci are involved in the action, and because the secondary focus must entirely take care of the realization of the pre-imagined action trajectory shape, the fingertips will definitely deviate at every position P from the perceptual image of the latent trajectory we had in mind. We do wish to perform that beautifully straight trajectory we have envisioned, but we simply cannot. The action trajectory shape is not directly controlled but secondarily, and therefore the fingertips will, at every position *P*, infinitely and randomly deviate from the perceptual image of the latent trajectory shape. It is thereby demonstrated that there must be a very heavy correction system present which mediates these deviations. The explanatory model connects them with the processing mechanisms of the perception[4], which do not consist of one, but of two pathways: the ventral and the dorsal stream.

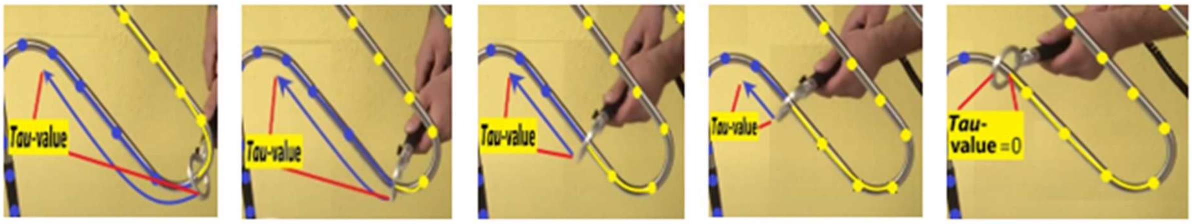
These two streams mediate all deviations within the entire phenomenon of the relationship between fingertips and action trajectory shape, like a marble within a marble run, in a double and reciprocal process. The ventral stream is primarily concerned with the processing of all perceptions toward the entire trajectory shape, while still maintaining awareness of the actual position P(0) of the fingertips. Conversely, the dorsal stream is primarily concerned with the processing of all perceptions toward the actual position P(0) of the fingertips, while maintaining awareness of the entire trajectory shape.

In this double and reciprocal process, the cortical streams correct each other in continuous alternation. They are therefore not activated in exact simultaneity, but because the reaction times are so short, it almost appears as if straight trajectory shapes are being created — which is clearly refuted in the execution of the nerve spiral[5].

The fingertips, in the transversal direction, will at every successive position infinitely and randomly deviate from the trajectory shape. These deviations along the x-axis are defined within the explanatory model as the *zigzag-process*. Likewise, an action object will always, at every successive position, infinitely and randomly deviate from the trajectory shape in the longitudinal direction. These deviations along the y-axis are defined within the model as the *accordion-process*.

These are difficult to visualize in an animation, yet driving a car or cycling without hand brakes provides an exact and tangible example of the autonomy of these two processes.

[4] https://www.explanatorymodel.nl/common-daily-actions/grasping/the-explanation-of-the-emergence-of-the-cortical-streams-we-can-only-guide-the-fingertips-to-a-coffee-cup-with-a-zigzag-movement-yet-the-ingenious-mediation-by-the-cortical-streams-creates-the-delusion-of-a-straight-action-trajectory-shape
[5] https://www.explanatorymodel.nl/common-daily-actions/the-nerve-spiral-game



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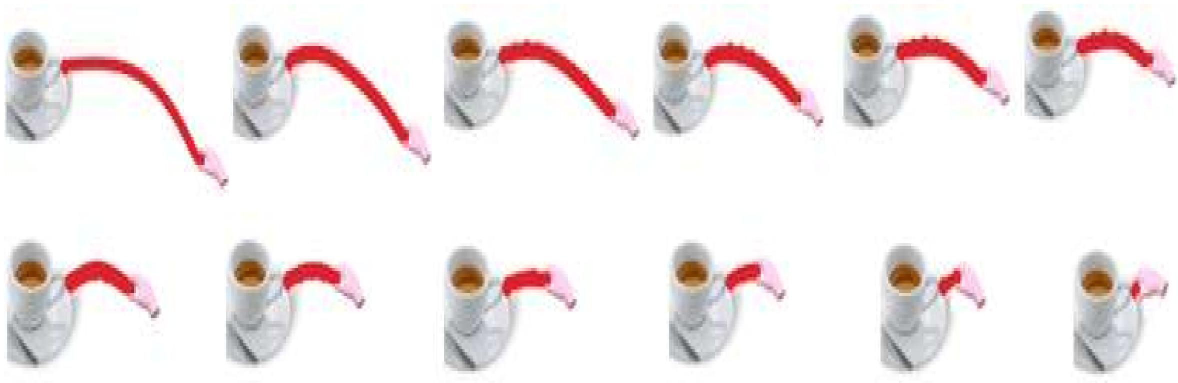
Illustrations: *Deviations are mediated, within every conceivable motoric action, in two autonomous ways: in width (form) and in length (line). It is difficult to visualize this within most actions. However, within driving a car or cycling (without hand brakes), one can clearly and unmistakably observe that the steering wheel can only mediate the zigzag-process, and the pedals can only mediate the accordion-process.*

The explanatory model of the motoric movement action shows that the act of grasping a coffee cup concerns a highly complex system — a system that would receive no ecological grounding at all, if it were not reducible to something very simple.



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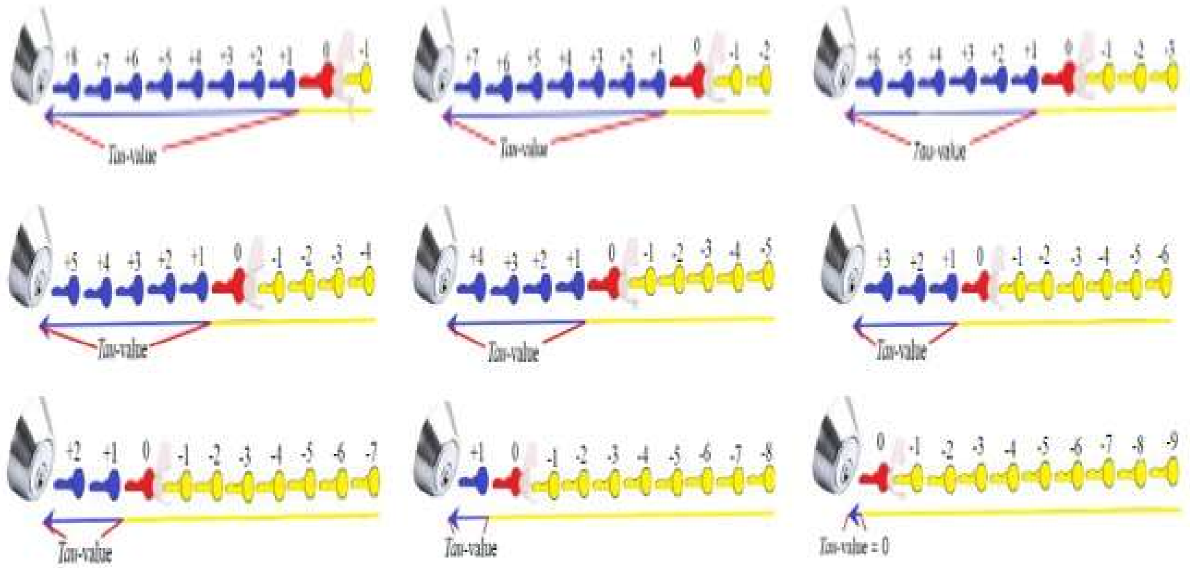
It must be remarked that under normal circumstances we observe the closing of the gap between the fingertips and the cup visually. But that is not the whole truth. In the subsequent explanations concerning the opening of a lock with a key, it will become abundantly clear that one primarily perceives the closing of the gap through visual perception. Nevertheless, proprioceptive perception will always remain present in a hybrid form. Thus, even though one mainly sees the closing of the simple line segment of the gap, one also always feels — proprioceptively — the closing of that same gap as the movement of the fingertips toward the coffee cup.

2. Opening a Lock with a Key[6]

The explanatory model of the motoric movement action has also shown with scientific evidence that, when opening a lock with a key, just as with grasping, there is always first an action trajectory shape constructed between the current position of the key tip and the lock[7]. It has furthermore demonstrated that we can only create the exclusively external line of the movement of the key tip by means of internal bodily movements[8] that extend only up to the outer surface of the key head. The movements belong to two entirely separated worlds, and therefore the internal and external perception are completely autonomous.



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[7] https://www.explanatorymodel.nl/common-daily-actions/opening-a-lock-with-a-key/lock-opening-prior-to-opening-a-lock-we-always-first-con-struct-a-perceptual-image-of-a-latent-action-tra-jectory-shape-out-of-the-perspective-of-the-key-the-scientific-evidence

[8] https://www.explanatorymodel.nl/common-daily-actions/opening-a-lock-with-a-key/opening-a-door-lock-with-a-key-requires-a-compelling-collaboration-between-an-internal-secondary-focus-and-an-external-primary-focus

in its essence concerns the reduction of the number of places between the key tip and the lock. The perspective of this motor action must therefore be regarded from the key tip, and not from the lock.

When opening a lock with a key, the main issue concerns the construction and execution of the external action trajectory shape — as solely that phenomenon reaches the lock — and therefore the primary focus must be directed toward it. The internal bodily movements are only important for realizing this main goal, and they therefore concern the secondary focus, which must consequently be pointed toward that action trajectory shape.

Due to the two autonomous foci, a peculiar figure arises during the act of opening a lock with a key, just as in every other motoric action. Solely the action trajectory shape — consisting of future key tip positions — will perform the very essence of the task, yet it can do nothing by itself. It can only be executed by a completely different, autonomous, internal movement. The explanatory model of the motoric movement action reveals, with this given, the most economical system ever conceivable. It shows that we are able to start moving the key tip from any random position, to stop it at any moment, to change its path, or otherwise. It shows that with a minimum of means a maximum output can be achieved.

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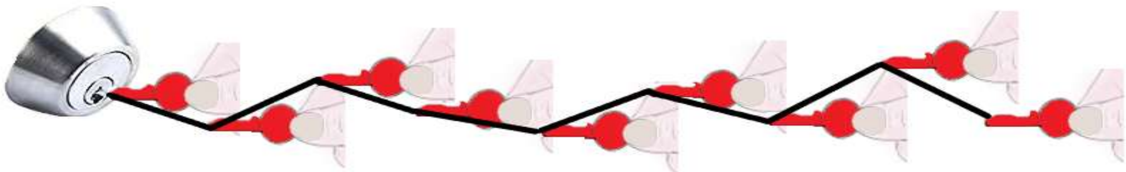
These two streams mediate all deviations within the entire phenomenon of the relationship between the key tip and the action trajectory shape, like a marble within a marble run, in a double and reciprocal process. The ventral stream is primarily concerned with the processing of all perceptions toward the entire action trajectory shape, while maintaining awareness of the actual position P(0) of the key tip. Conversely, the dorsal stream is primarily concerned with the processing of all perceptions toward the actual position P(0) of the key tip, while maintaining awareness of the entire action trajectory shape.



In this double and reciprocal process, the cortical streams continuously correct each other in alternating succession. They are therefore not activated at every time interval simultaneously, but because the reaction times are so short, it almost appears as if straight action trajectory shapes are being created — which is clearly refuted in the execution of the *nerve spiral*[10]. The key tip, in the transversal direction,

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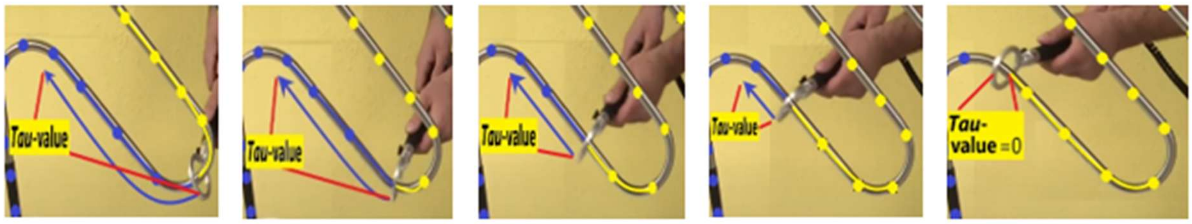

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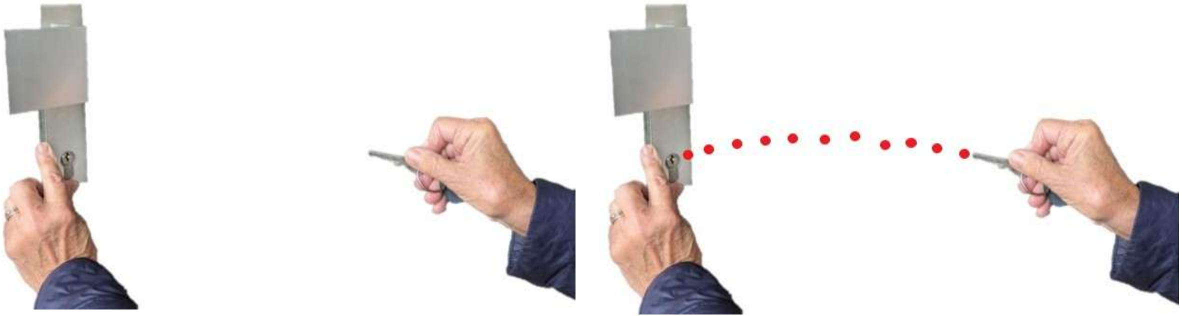
It must be remarked that under normal circumstances we observe the closing of the gap between the key tip and the lock visually. But that is not the whole truth. In the subsequent explanation concerning the opening of a lock with a key within pitch black darkness, it will become abundantly clear that one primarily perceives the closing of the gap through visual perception. Nevertheless, proprioceptive perception will always remain present in a hybrid form. Thus, even though one mainly sees the closing of the simple line segment of the gap, one also always feels — proprioceptively — the closing of that same gap as the movement of the fingertips toward the coffee cup.

3. Opening a Lock with a Key Within Pitch Black Darkness

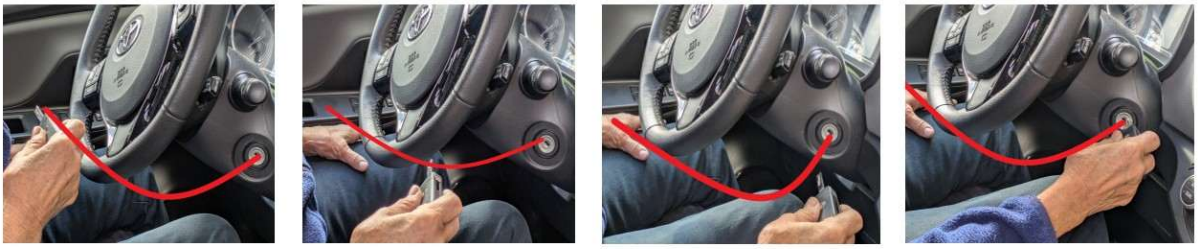
The transition from opening a lock in daylight to performing precisely the same task in pitch black darkness will reveal many fundamental aspects. It will show that every motor action is always carried out through a *hybrid* form of perceptual processing. Which stands in sharp contrast to the prevailing assumption within contemporary science. The dominant belief still holds that only one type of perceptual process is involved in a motor action, and that it always occurs in a fixed constellation.

When we want to execute actions in complete darkness, a perceptual image of the action trajectory shape must still first be created. This can be achieved by using the non-key hand to first locate the lock and then placing that hand near the lock. By combining previous cognitive knowledge of the (familiar) lock with this haptic perception, we can now construct an action trajectory shape between the key tip (which we perceive proprioceptively at a distance) and the keyhole (which we now perceive proprioceptively in direct contact).



Illustrations: *In total darkness, we place the non-key hand at the lock. The entire action is then carried out identically to the procedure in daylight. The novum here, however, is that the three obligatory foci are now perceived completely proprioceptively: 1. The movement of the lock, 2. The external movement of the key tip (primary focus), and 3. The internal bodily movements directed toward the key head (secondary focus).*

With this action trajectory shape, one can now, exactly as in the previous description where visual perception was possible, reduce the *tau*-value to zero through the cooperation of the two foci and the mediation of the cortical streams within the zigzag and accordion processes, and thus execute the action successfully — purely through proprioceptive perception. In here it must be remarked that the perception of the hand placed at the lock coincides with the perception of the end of the action trajectory shape — which in practice makes no difference — but that, in essence, it concerns the perception of the hand itself. We must therefore keep the non-key hand positioned at the lock.



Illustrations: *In an unfamiliar vehicle, the process of starting the car must first be calibrated, which often provokes the visual location of the ignition slot. However, with repeated execution, an implicit perceptual image of the action trajectory shape develops, which is internalized as a cognitive template after just a few repetitions. This results in an autonomous representation capable of guiding the motor execution without any visual control. Solely depending on proprioceptive perception processes.*

The action is therefore executed entirely through proprioceptive perception. Within this, a unique insight emerges: that the primary and secondary focus originate directly from this dual perceptual engagement. It thereby demonstrates that proprioceptive perception must contain *two autonomous phenomena*. The explanatory model of the motoric movement action aligns these with the known phenomena regarding proprioceptive perception: *limb position* and *movement*[11].

Within the context of this article, however, the most crucial point is that proprioceptive perception does not disappear when we open a lock in daylight. It remains the foundational layer of all perceptual processing. The breakthrough insight lies in the realization that even when we *see* the key moving along the action trajectory shape toward the lock, we also *feel* it — always, and inevitably, in a hybrid form.

B. Motor Actions with One's Own Body as Environmental Object

From actions involving an external environmental object, the transition is now made to those motor actions in which the end point of the action trajectory shape concerns a part of one's own body. The conclusion will show that there is no essential difference in how these action trajectory shapes are created, nor in how the cortical streams must mediate their execution *online*.

This section gradually builds toward the phenomenon of *self-tickling*, demonstrating that a multitude of egocentric perceptual processes must be activated in such cases — processes that render the experience of an "unexpected" tickling sensation absolutely impossible.

Beyond providing a complete description of the *tickling paradox*, this part also delivers the comprehensive explanation of how all parts of our body relate to one another within our perceptual processes. This, in turn, gives rise to the final and complete clarification of *The Rubber Hand Illusion*.

1. Head, Shoulders, Knees and Toes

Once the insight has been established that we can create an action trajectory shape between two hands solely through proprioceptive perception, as explained within the key task, it becomes evident that such action trajectory shapes can also be formed between *all* parts of the body. In relationship to which it can be remarked that these shapes are latently present between every conceivable pair of body parts, yet they only become relevant within an *egocentrically formulated intention* — they are activated only when attention is directed toward them.

[11] Proske, U., & Gandevia, S. C. (2012). The proprioceptive senses: their roles in signaling body shape, body position and movement, and muscle force. *Physiological Reviews, 92*(4), 1651–1697.

As an illustrative example, the international children's song and dance *Head, Shoulders, Knees and Toes*[12] is taken. The explanation follows precisely the same principles as the grasping process described earlier with the coffee cup. The only difference here is that the end point of the action trajectory shape now concerns a body part of one's own.

Illustrations: *At the moment when both hands are positioned on the head as their starting point, we can, from both hands simultaneously, construct and execute action trajectory shapes toward any other part of the body. With some practice, we can even perform separate action trajectory shapes at the same time — for instance, one toward the shoulder and one toward the knee (or combinations such as belly–knee, ear–hip, and so forth). Within this children's dance, however, the movements are synchronous. It can be noted that they ultimately form two autonomous yet perfectly mirrored templates. Like within the coloured image.*

In precisely the same way, the action trajectory shapes within this children's dance are created as they are when grasping a coffee cup or opening a lock with a key. The cortical streams must therefore mediate the autonomous action trajectory shapes of both the left and the right hand.

One can observe that the distances between the respective body parts differ, and yet the system is able, through the previously described *zigzag* and *accordion processes*, to mediate the deviations of the hands within the significant action trajectory shapes perfectly in rhythm with the music.

As the song comes to its conclusion, the index finger must also be brought to the tip of the nose. At this very moment, the *nerve spiral game* once again comes into play, revealing that all action

12 https://www.youtube.com/watch?v=S2eRNzsAZg4

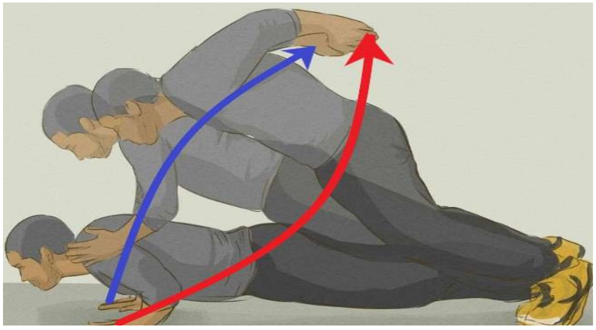
trajectory shapes — including those within this dance — can never be executed identically c.q. will always undergo a *zigzag process*.

When the music is played slowly, there is sufficient time to mediate the deviations, and the tip of the nose will usually be reached directly. However, when the tempo of the music exceeds a certain threshold, it can be observed that the fingertip will regularly miss the exact tip of the nose.

The explanation is simple: the hands constitute relatively large surfaces, which can compensate for a great many deviations within their own size. In short, if one had to bring the palm of the hand to the nose, the action would never fail. However, because the index finger represents a relatively small surface, even minimal deviations within the action trajectory shape toward the nose will have a far greater effect.

2. Clapping the Hands Behind the Back

The example of bringing the index finger to the nose, or bringing food to the mouth, already demonstrates that visual perception is not essential for the successful execution of a motoric action. To substantiate this principle with convincing evidence, the act of clapping the hands behind the back will now be examined in more detail.



Illustrations: *It makes no difference whether we clap our hands in front of or behind the back. In both cases, we create from each hand an autonomous action trajectory shape directed toward a point of intersection between the two lines. Although we could in principle observe this process in front of us visually, we usually perform it predominantly through proprioceptive perception. Due to the fact that we can proprioceptively feel the tau-values of both action trajectory shapes approaching zero with great accuracy, it is even possible to execute a crescendo within the clap itself.*

When clapping the hands there are, as in the dance Head, Shoulders, Knees and Toes, two moving body parts with two autonomous action trajectory shapes. This makes the action more complex than a motor action requiring only a single trajectory shape to be created and executed. Nevertheless, we can easily bring the hands together, because the deviations within each action trajectory shape are never large enough to cause one hand to miss the other. Moreover, we can add a *crescendo* to the actual clap purely through proprioceptive awareness. Thus, we can feel with remarkable precision the moment when the *tau-value* between the hands approaches zero.

3. Tickling

With all the preceding explanations, it can now be made crystal clear why *being tickled* differs so profoundly from *tickling oneself*.

When one is being tickled — no matter how predictable the situation may seem — it represents, from an evolutionary and ecological perspective, an *attack* on the body. Such an event triggers a basal haptic alertness of the organism, a readiness to face a potential struggle of survival. The body therefore prepares itself for a (tickling) attack, yet the attacker (the tickler) conceals the lines of the attack within two autonomous phenomena: *time* and *form*.

Within being tickled we do not plan anything ourselves, as we do in all previously discussed motoric actions, and the (tickling) attack remains uncertain in both time and place until the very last moment. This sustained uncertainty, this perceptual impossibility to anticipate, generates the maximal tickling sensation.

With all the preceding information, it becomes equally clear why *tickling oneself* is fundamentally different. In self-tickling, all of the conditions described above disappear. One cannot attack oneself, and one cannot engage in any motoric act toward one's own body without already knowing the exact *action trajectory shape* that connects the acting effector to the target area.

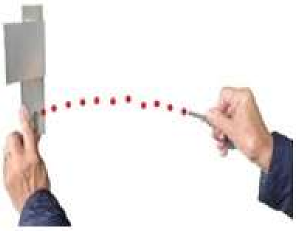
Every self-directed movement is therefore preceded by a precisely anticipated and proprioceptively formed action trajectory. The cortical streams need to heavily mediate this process, the body already knows the location, and the hand already knows the time-to-contact c.q. the *tau*-value. Thus, no element of surprise can ever arise and it is precisely that absence of uncertainty — that perfect internal mediation of time, space, and intention — which abolishes the tickling effect altogether.

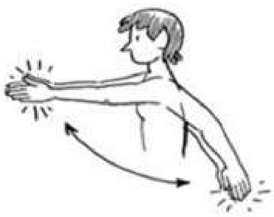
Part 2

Latent Proprioceptive Action Trajectory Shapes That Exist Between All Body Parts Can Become Manifest When Attention Is Intentionally Allocated

1. From Action Trajectory Shapes Within Motor Actions to the Existence of Latent Proprioceptive Connections Between All Body Parts

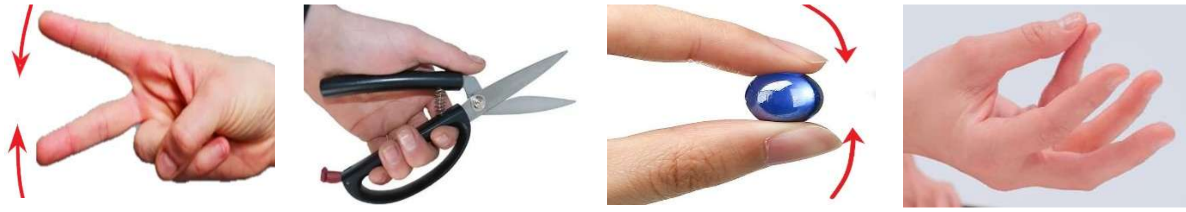
The previous section showed that, within motor actions, action trajectory shapes can be created between a wide variety of body parts. A substantial portion of everyday motor behavior involves moving the hand, fingertips, and forearm toward another part of the body. This may lead to the mistaken impression that forming a perceptual image of an action trajectory shape is exclusively related to movements of the hand toward another bodily location. This is a misconception. When attention is directed, we can form action trajectory shapes between *any* two body parts.



Hand–Fingers

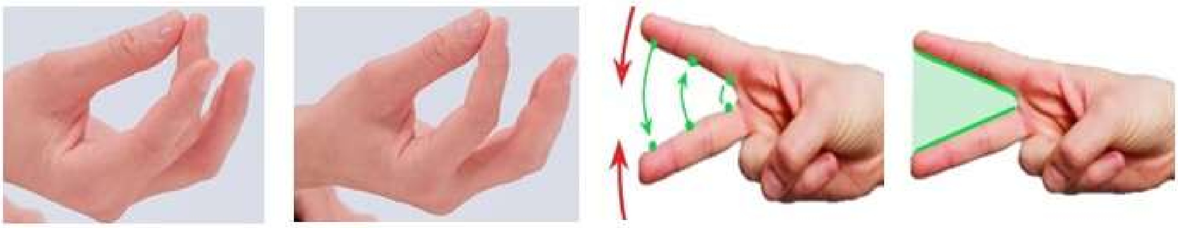
Within all subdivisions of the hand, action trajectory shapes can likewise be formed. The fingers—and even the subsegments of each finger and hand region — can be brought toward one another through a specific action trajectory shape. This underlies hand gestures, tool use, snapping the fingers, and all forms of grasping. For each of these action trajectory shapes, we possess extensive cognitive knowledge concerning their form, their *tau*-value[13], and the manner in which they are mediated by the cortical streams[14].



The essence of the explanation of the RHI is that a perceptual image of a latent action trajectory shape is created *only* when attentional focus is allocated to the relevant body parts. In all hand- and finger-related movements, we therefore know precisely which end effector(s) the attentional focus is directed toward. Internally, we can feel exactly when the fingers reach their point of maximal separation (amplitude), and we equally sense all intermediate phases as they move toward complete closure. None of these proprioceptive experiences requires any visual perception.

Hand–Fingers 2

If we now solely zoom in on the possible relational configurations within the index–middle–thumb constellation, an extremely large number of distinct possibilities emerges. The fingertips of all three fingers can be brought toward one another in multiple independent ways. The thumb and middle finger, for example, can move autonomously toward each other in either direction (Fig. 1), but all hybrid combinations between the two are equally possible. In addition, within the relationship between any two fingers, individual points along each finger (Fig. 3) can be moved independently in both directions, and even entire surface regions can be brought toward one another (Fig. 4). In this latter case, a complete geometric form may emerge, such as the shaded light-green triangle.



1 2 3 4

The essence of the explanation of the RHI is that a perceptual image of a latent action trajectory shape is created *only* when attentional focus is intentionally allocated to the relevant body parts. In all hand–finger movements, we therefore know precisely which end effector(s) the attentional focus is directed toward at the moment of execution. This attentional focus can also be distributed across multiple latent action trajectory shapes simultaneously—a fact that can be empirically observed when lifting a cup or handling a heavy saucepan. Consider also piano playing[15], in which action trajectory shapes must

[13] https://www.researchgate.net/publication/373862466_Within_grasping_the_essence_of_the_task_is_solely_executed_by_the_external_movements_of_the_fingertips_toward_a_coffee_cup_Within_the_primary_focus_the_fingertips_are_constrained_within_an_action_traj?_sg%

[14] https://www.researchgate.net/publication/380186699_The_explanation_of_the_emergence_of_the_cortical_streams_-_We_can_only_guide_the_fingertips_to_a_coffee_cup_with_a_zigzag_movement_yet_the_ingenious_mediation_by_the_cortical_streams_creates_the_delus

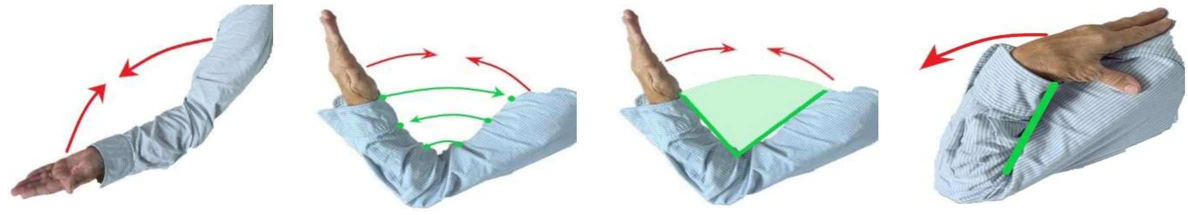
[15] https://www.researchgate.net/publication/389847547_The_complete_behavioural_clarification_of_piano_playing_and_sequential_learning?_sg%5B0%5D=MWLOACaRyovQ-Qutu-udxE0V_rpgcFIWF1Y4-

sometimes be formed between ten fingertips and ten separate keys. Even if one could argue that a single overarching focus-image may be involved, the underlying complexity is substantial.

For each of the action trajectory shapes within the hand–finger relationship, we possess extensive cognitive knowledge of their form, their *tau*-value, and the manner in which they are mediated by the cortical streams.

Upper Arm–Forearm

The relational possibilities between two fingers can be found in an identical manner within the relationship between the upper arm and the forearm. The forearm and upper arm can be moved toward one another in just as many distinct ways as the fingers can.



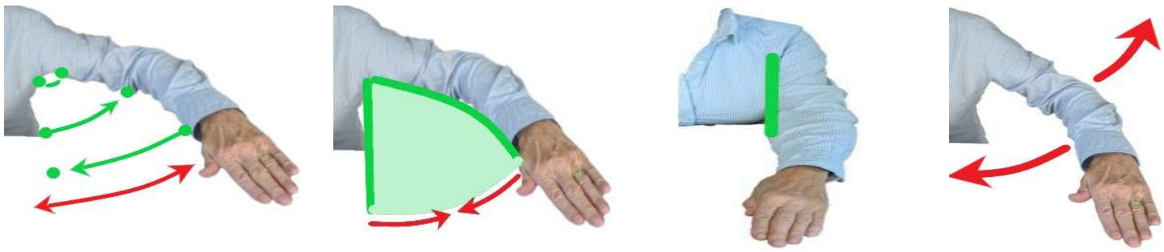
1 2 3 4

The essence of the explanation of the RHI is that a perceptual image of a latent action trajectory shape is created *only* when attentional focus is intentionally allocated to the relevant body parts. Extension and flexion of the arm can therefore be achieved through a complex multitude of attentional reference points. Here, too, a complete geometric form may emerge (the shaded light-green surface).

For each of the action trajectory shapes within the upper arm–forearm relationship, we possess extensive cognitive knowledge regarding their form, their *tau*-value, and the manner in which they are mediated by the cortical streams.

Arm–Torso

The relational possibilities between the arm and the torso follow the same principles as those between two fingers or between the upper arm and forearm. The arm and torso can be brought toward one another in just as many distinct ways as in those previous cases.



1 2 3 4

The essence of the explanation of the RHI is that a perceptual image of a latent action trajectory shape is created *only* when attentional focus is intentionally allocated to the relevant body parts. Adduction

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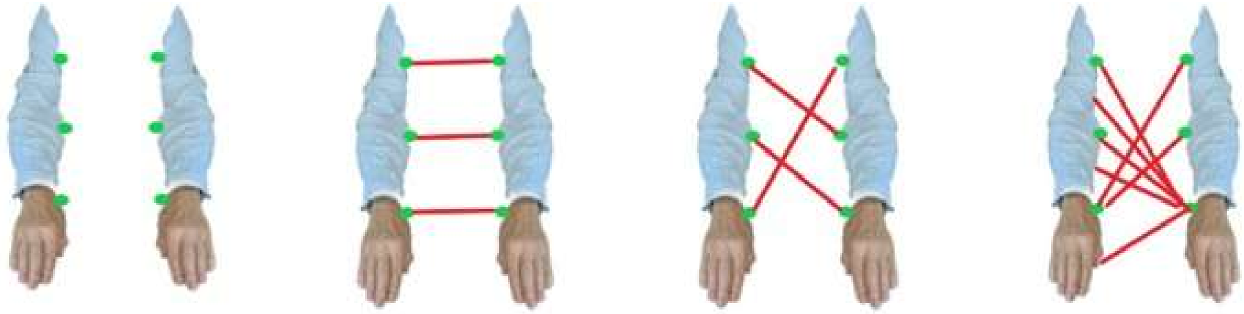
and abduction of the arm can therefore be achieved through a complex multitude of attentional reference points. Here again, a complete geometric form may emerge (the shaded light-green surface).

For each of the action trajectory shapes within the arm–torso relationship, we possess extensive cognitive knowledge regarding their form, their *tau*-value, and the manner in which they are mediated by the cortical streams.

Arm–Arm

In the first part, clapping the hands—both in front of and behind the body—was fully discussed. That phenomenon involves attentional focus on two action trajectory shapes extending from the palms (palmar surfaces) toward one another. However, when we are *not* clapping, two arms positioned side by side contain a vast number of complex relational possibilities.

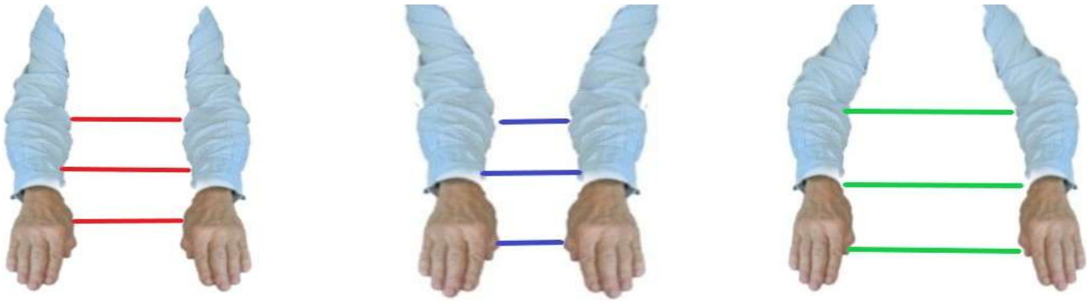
Arm-arm I



1 2 3 4

If we consider only three (green) points on each arm (Fig. 1), and we allocate attentional focus to them, we can bring all of these points toward one another in parallel and reciprocal fashion (Fig. 2). Yet this configuration is not constrained to parallel movement; any of the points can be moved toward any point on the other arm in arbitrary combinations (Fig. 3). In reality, this would lead to an overwhelming multitude of possibilities (Fig. 4).

Arm-arm II



1 2 3

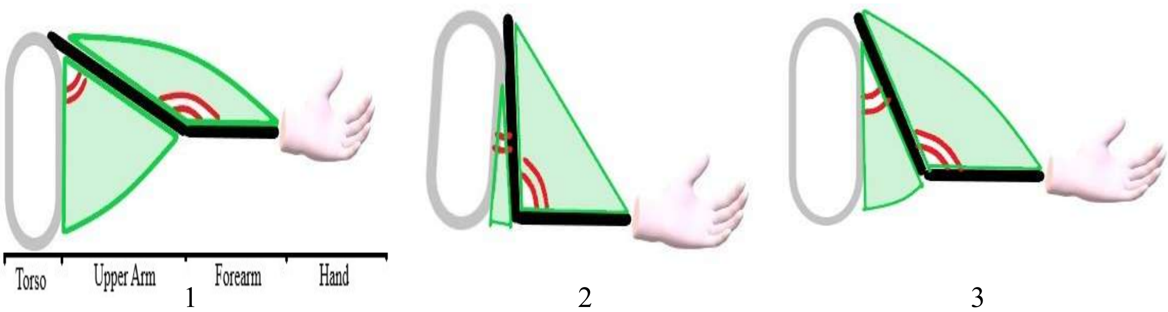
When two arms are placed next to each other, we can, under attentional focus, judge the relative distance between the forearms remarkably well. We form relations expressed as action trajectory shapes toward the other arm and then compare the perceived outcomes. We clearly feel that the blue line (Fig. 2) represents the shortest trajectory, whereas the green line (Fig. 3) represents the longest. Although the perceptual image of the adduction–abduction angle certainly plays a role here, it does not constitute absolute knowledge. When the arms lie on a table in nearly identical configurations, it becomes significantly more difficult to make accurate (relative) judgments.

Arm-arm III

1 2 3

Even when the arms are not parallel on a table, we can, without any visual perception, feel the form they collectively describe. This is not absolute knowledge either, but when attentional focus is allocated, we are well able to form perceptual images of clear (relative) deviations between the arms. Within certain limits of fluctuation, we therefore know—and feel—how parts of one arm relate to the other, and which geometric configuration emerges from that relation.

Arm-arm IV



1 2 3

As a final example, we turn to the proprioceptive perception of the angles formed by the relevant body segments when one arm—such as in the RHI—is placed on a table. In the three illustrated configurations, clear (relative) differences can be felt in the angles formed by the segments of the arm[16]:

1. the angle between the forearm and the upper arm,
2. the angle between the upper arm and the torso, and
3. the overall geometric figure that these segments collectively create.

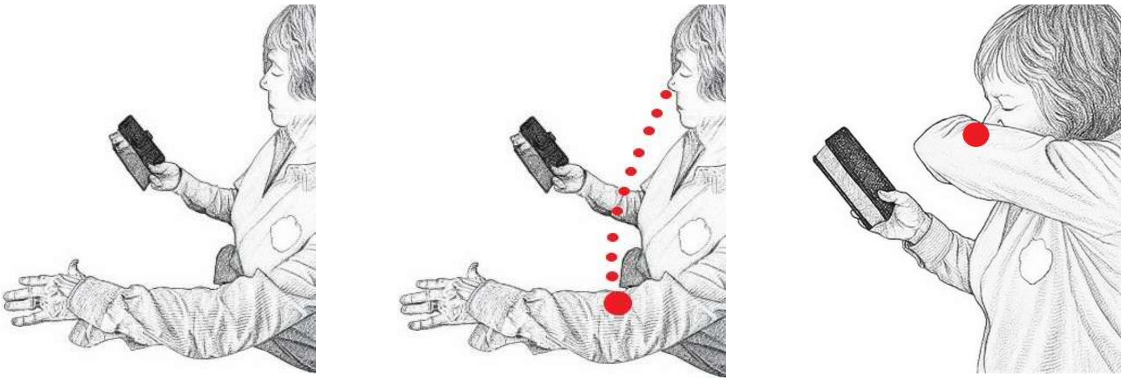
When these three differ distinctly, you can immediately determine, through visual perception alone, which arm is yours.

Summary Providing the Conceptual Basis for the Later RHI Analysis

When we place an arm on a table and direct our attention elsewhere, we experience no proprioceptive awareness of that resting arm. For example, if you hold a book with the other hand and engage in

[16] The constellation of inclination angles and the geometric figures within a single posture exhibit stable, cognitively recognizable values.

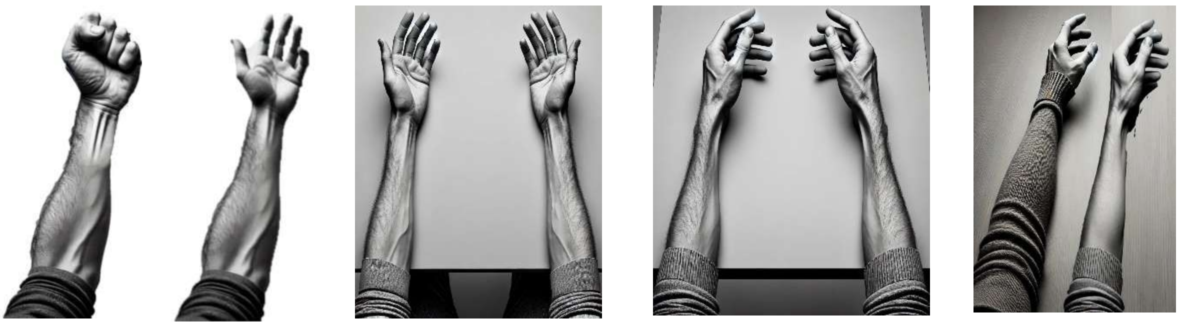
active reading, the arm on the table disappears entirely from your perceptual field—both during and after the activity.



However, if a sudden sneeze occurs, attentional focus is redirected to the elbow within milli-seconds. Drawing on extensive cognitive knowledge of the elbow's potential movements, a latent action trajectory shape becomes manifest, allowing you to guide the elbow precisely toward the nose. Without the ability to mediate the *tau*-value of this trajectory through the cortical streams, you would repeatedly strike your nose—an outcome prevented entirely by the attentional activation of the latent proprioceptive structure[17].

This observation begins to reveal the principles that underpin the RHI. A passively resting arm is known to be one's own only because no competing limb is present nearby. Crucially, the visual perception of the external surface of the arm has no intrinsic relationship to the proprioceptive perception of the internal arm. A sense of body ownership arises only when these two autonomous perceptual worlds become causally coupled through self-generated motor action.

Whenever we initiate movement—such as with the fingertips—we generate internal proprioceptive change that *causes* (!) the external surface to move. Through this causal chain, the brain rapidly establishes the linkage between internal and external perception: we continuously monitor external movement[18] to confirm and refine internal proprioceptive signals. This is the mechanism by which the two perceptual domains are normally unified.



1 2 3 4 5

So, if you don't move anything in the arm, the only possible conclusion about which arm is yours depends on whether the internal proprioceptive configuration matches the external visual image. When you internally feel your hand forming a fist (Fig. 1), you match that sensation to its corresponding visual configuration; when the fingers are extended (Fig. 2), you match it to another. Perception thus proceeds from inside to outside: we verify visually whether the proprioceptive representation is correct.

[17] This principle was already demonstrated in Part 1 ("Touching the Nose with the Index Finger"), where the rapid, attention-driven emergence of a latent action trajectory shape enables precise movement toward the nose.
[18] Which likewise represents the essential mechanism underlying driving, cycling, walking, and all comparable everyday motor actions.

The same holds when two arms lie in clearly different positions on a table (Fig. 3 and 4)—you will always match vision to proprioception when the internal configuration is unambiguous. The proprioceptive feel of clothing on the skin (Fig. 5) functions in the same way.

1

2

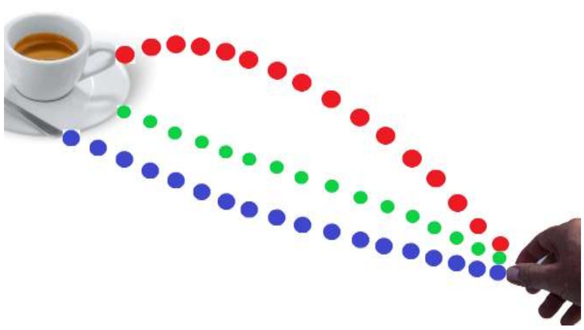
So, if three arms were placed before you in clearly distinct poses (Fig. 1), you would visually identify your own arm immediately. But if the postures were too similar (Fig. 2), internal proprioception alone would not allow identification; movement would be the only resolution.

The RHI revolves around an unusual and practically irrelevant motoric action. In everyday life, whenever we intend to use an end effector, we direct attentional focus toward it to initiate movement. Although the present section clarifies the order and mechanism by which this occurs, such processes never cause difficulties in ordinary behavior. They become problematic only in the artificial, passive conditions of the RHI—conditions in which attentional focus is prevented from activating the relevant latent action trajectory shape.

Part 3

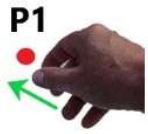
Two Autonomous Foci — The Visual and Proprioceptive Perception of the Hand Belong to Two Incompatible Worlds

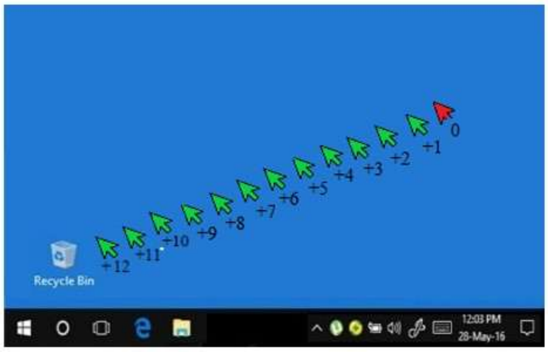
The current scientific view still assumes a single, undivided focus during the execution of motor actions. In contrast, the explanatory model of the motoric movement action shows that every conceivable action necessarily involves three distinct foci. The perception of the movement of the environmental object constitutes one focus, whereas the perception of the egocentric movement always consists of two autonomous foci. Thus, when we intend to grasp a coffee cup, one focus is continuously directed toward the cup itself, while the other two foci monitor the egocentric movement of the fingertips toward the cup.



The egocentric movement must proceed along an action trajectory shape for which a perceptual image has been created immediately prior to execution. This perceptual image is grounded in how the cup must ultimately be pressed and stabilized after a touching process[19], but it is equally dependent on all the places P that the fingertips must traverse in continuous succession in order to complete the action successfully.

Although it is likely that we imagine these action trajectory shapes as smooth and linear within the tactical motor action (TMA), the dual-focus structure of egocentric movement prevents such simplicity. Because the two autonomous foci must coordinate through alternating processing in the cortical streams, every action produces a zigzag pattern that only *appears* straight[20]. Without such a perceptual blueprint, no movement could even begin, because the system would have no basis for determining the first place P toward which the fingertips need to move. The scientific literature has never fully recognized that grasping a cup is fundamentally a bridging process.





Moreover, the explanatory model shows that the fingertips ultimately carry out the essential part of the action, even though they themselves cannot initiate or produce movement. Though composed of living cells, the fingertips are incapable of self-motion. They can traverse an external action trajectory shape only through internal movements. Consequently, the perception of external movement is entirely separate from the perception of internal movement; these belong to two incompatible perceptual worlds.

When we initiate fingertip actions, this becomes evident. Through extensive cognitive knowledge, we know approximately which region of the fingertips must traverse the action trajectory shape. Yet this knowledge is not exact. At the beginning of the movement, we therefore check—within an extremely fast feedback loop—whether the movement unfolds as intended. This is analogous to the movement of a pointer on a computer screen: visual perception can only monitor whether the action proceeds as tactically planned.

A remarkable phenomenon arises here. Through visual perception, we first determine a planned action trajectory shape, but nothing motoric happens at that stage. Only when the action begins do we generate internal movements—movements constrained by extensive cognitive knowledge—and then visually confirm whether the fingertips indeed follow the planned action trajectory shape. This process continues throughout the entire action. The system therefore operates with a constant gap between

[19] It is important to note that the prevailing scientific assumption is incorrect. Grasping actions are currently conceptualized as *reach-to-grasp movements*, whereas in reality they are *touch-to-push actions*.
[20] https://www.researchgate.net/publication/380186699_The_explanation_of_the_emergence_of_the_cortical_streams_-_We_can_only_guide_the_fingertips_to_a_coffee_cup_with_a_zigzag_movement_yet_the_ingenious_mediation_by_the_cortical_streams_creates_the_delus?_sg%5B0%5D=ZJlqPe4RqhCz2hW6J5FWHRnu209TW6C8vIT3lnF-beNyVAYafIwPA6bGflWVKZ0T81OOmxJRbnJHgRCmOoLJAH7G4bdhuH2qKCi-lYXOwm.wHkiOHD8YsMzRezrknvz2lgI6wqxB8sg4ekoKaT6i3c2UnLlsM6wu65AKYFgTMQsH1vTeFaW-tcECEMR_ZUJRyg&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6ImhvbWUiLCJwYWdlIjoicHJvZmlsZSIs-InBvc2l0aW9uIjoicGFnZUNvbnRlbnQifX0

intrinsically *arbitrary* (!) internal movements and the visual confirmation of their outward consequences.

The same structure appears in all motor actions. Car driving[21] is a particularly clear example. When driving forward or reversing, we select one specific attentional focus; simultaneous representation of both perceptual streams would interfere with execution. Because the two autonomous foci operate independently, we can influence only the steering wheel and pedals, and must continually engage in an immediate feedback loop to establish a causal relation between these internal movements and their external consequences along the intended trajectory.

The relevance for body ownership becomes striking in the context of a racing game. If you did not know which of the two cars you controlled, you would make a series of arbitrary movements with your controller to visually determine which car displays a causal response. Only through this causal coupling can ownership of the action be established.

[21] https://www.researchgate.net/publication/382337498_The_complete_clarification_of_all_functional_perception_processes_within_car_driving?_sg%5B0%5D=ZJlqPe4RqhCz2hW6J5FWHRnu209TW6C8vIT3lnF-beNyVAYafIwPA6bGflWVKZ0T81OOmxJRbnJHgRCmOoLJAH7G4bdhuH2qKCi-lYXOwm.wHkiOHD8YsMzRezrknvz2lgI6wqxB8sg4ekoKaT6i3c2UnLlsM6wu65AKYFgTMQsH1vTeFaW-tcECEMR_ZUJRyg&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6ImhvbWUiLCJwYWdlIjoicHJvZmlsZSIs-InBvc2l0aW9uIjoicGFnZUNvbnRlbnQifX0

Part 4

The Rubber Hand Illusion

When we finally turn to the role of the arms within the Rubber Hand Illusion (RHI), a crucial insight emerges: the RHI is *not* a motor action. What participants are asked to do in these experiments—explicitly judge whether a presented hand feels like their "own"—is not an everyday phenomenon but an exceptional and evolutionarily almost irrelevant situation. In daily life, the question of ownership is never raised; ownership is not normally *perceived* but rather *generated* through motor-causal coupling between two autonomous perceptual domains: the visual perception of the external surface of the hand and the proprioceptive perception of its internal movements.

This point goes to the heart of why traditional multisensory integration models fail. As long as no motor coupling occurs, the two perceptual foci remain entirely autonomous, and the system, precisely because there is no discrepancy to resolve, can allow any visual manifestation to stand uncontested. It is exactly this motoric inactivity that creates the conditions under which the RHI can arise.

1. Why the Arm Normally Not Becomes Manifest

In an ordinary situation, such as reading a book, the other arm simply rests on the table. Only one action trajectory shape is manifest: the one directed toward the book. The major ecological advantage of this, central to the ontological framework of this article, is that the nervous system is not forced to keep thousands of latent trajectories between all possible body parts continuously manifest. Such a state would lead to unmanageable and non-functional sensory overload. From an evolutionary perspective, only a system in which latentness is the default mode, and in which manifestation arises solely when attention is directed toward a specific relation or action, could have survived.

A sudden sneeze demonstrates this principle perfectly: only at the moment when the relevant body part—the nose—becomes "problematic" does the latent action trajectory shape toward the elbow become manifest. The structure is always present, but it remains latent until the situation demands its manifestation.

2. The Role of Perceptual Threat: The Approach of a Hammer

The same mechanism appears when, during reading, a hammer suddenly approaches in the peripheral visual field—a principle that is also implicitly at work in many RHI setups. Again, no motor action is performed, yet the three phases of perceptual detection reveal how latent bodily relationships become manifest: 1. Initially, solely motion is detected, through the continuous comparison of temporal images across the peripheral field, 2. Next, it becomes apparent that the successive visible positions of the movement form a geometric pattern—a manifest action trajectory shape—whose latent continuation may intersect with the (zero-)movement of the resting hand, 3. Only then is the object recognized, revealing that the approaching entity is a hammer.



Thus, contrary to standard interpretations of RHI procedures, this demonstrates that the mere appearance of an approaching hammer or brush is already sufficient to draw attention to the relevant body region. Attention is not triggered by touch alone but by the bare approach—the emergence of a latent action trajectory shape whose projected continuation threatens to intersect with the body.

3. This Principle Within the Rubber Hand Illusion

In RHI setups, the rubber hand may be positioned either above or beside the real hand, usually with a visual partition to avoid immediate confusion. The real arm is covered so that even peripheral vision confirms that the presented hand cannot be one’s own. The two hands must lie close together; if the spatial discrepancy becomes too large, a clear proprioceptive–visual mismatch occurs, and the phenomenon disappears instantly.


Crucially, no motor action is ever required in RHI procedures. Participants are not asked to move; they are merely asked to report whether a causal relation is felt with the artificial hand. This is precisely why the phenomenon can arise: as long as no motor coupling is generated, the proprioceptive trajectory structure remains latent and visual manifestation can dominate on its own. Attention is directed toward the rubber hand through a simultaneous visuo-tactile stimulus with a brush—participants see the rubber hand being stroked while their own (hidden) hand is touched at the same time. Yet the explanatory model introduces a fundamental novum here: even before actual touch occurs, the mere approach of the brush already renders a latent action trajectory shape toward the relevant region becoming manifest. Just as with the approaching hammer, it is the anticipated movement of an external trajectory—the threat of impending contact—that forces attention toward the body part.

4. Why This Is Not an "Illusion" but a Pre-Actional Uncoupled State

When we reconsider the central insights developed earlier, it becomes clear that the RHI is not the result of misleading multisensory integration, but of a brief *pre-actional* state in which: 1. The visual focus is allowed to become manifest, 2. The relevant proprioceptive action trajectory shape remains latent, and 3. No motor-causal coupling is activated.

Only when motor intention arises does the latent proprioceptive structure become manifest at high speed and become coupled to the visual perception of the hand's external movement. In the very first milliseconds of a motor action, feedback becomes necessary and the coupling between the two autonomous perceptual domains is immediately forced. It is precisely at that coupling moment that the RHI—as traditionally described—would normally collapse.

Thus, the RHI does not reveal an illusion but a historically misinterpreted scientific phenomenon: the shortest possible temporal window between the completion of the Tactical Movement Action (TMA) and the onset of the first motor-driven causal coupling. Within that window—so brief that it is barely measurable—visual manifestation can exist without a proprioceptive counterpart. RHI research has taken this exceptional (short) phase, isolated it experimentally, and reified it as an "illusion," whereas it is in fact the natural consequence of the fundamental architecture of egocentric motor action.

Discussion

The present manuscript proposes a mechanistic framework that fundamentally reshapes how the Rubber Hand Illusion (RHI) has been interpreted for more than two decades. Rather than viewing the phenomenon as a failure of multisensory integration or a distortion of a unified body representation, the explanatory model offered here situates the RHI within the architecture of egocentric motor action. This reframing has several theoretical and empirical implications.

First, the analysis demonstrates that the RHI does not reveal a malfunction or misintegration of sensory inputs but instead exposes a rare pre-actional state in which visual manifestation is permitted to dominate because proprioceptive action trajectory shapes remain latent. This state occurs only when motoric coupling is actively suppressed—precisely the condition engineered in RHI experiments. As such, the effect is not an "illusion" in the sense of perceptual deception; rather, it is the predictable outcome of a configuration in which the causal binding between two autonomous perceptual domains is intentionally withheld.

Second, the model clarifies longstanding inconsistencies in the RHI literature. Phenomena such as the dissociation between proprioceptive drift and ownership, the weakening of the illusion under active movement, and the involvement of premotor areas in the absence of overt motor commands have been difficult to reconcile within multisensory integration frameworks. By grounding ownership in motor-driven causal coupling, these discrepancies no longer appear anomalous. Drift reflects a visual recalibration process, whereas ownership requires the initiation of a proprioceptive trajectory—hence why the two do not always covary. Similarly, active movement dissolves the illusion because movement forces proprioceptive manifestation, thereby re-establishing the dominance of internal dynamics over external visual input.

Third, the model emphasizes that perception of the external surface of the body and perception of internal movement belong to two incompatible perceptual worlds. Traditional accounts presuppose that visual, tactile, and proprioceptive inputs converge into a single, continuously manifest body schema. The present framework instead shows that such a schema cannot exist in a manifest form without producing unmanageable computational overload. Only a latent, attention-dependent architecture is evolutionarily plausible. The RHI becomes understandable only when this latent–manifest distinction is taken seriously.

Fourth, the role of stimulus approach—whether a hammer in peripheral vision or a brush in an RHI experiment—reveals a mechanism largely overlooked in prior work. The system detects the potential intersection of an external action trajectory with the body before it identifies the object itself. This mechanics-first logic explains why attention is drawn to a body part even prior to contact, and why synchrony of stimulation alone cannot constitute a sufficient explanation. The RHI capitalizes on this naturally occurring attentional mechanism by directing visual focus to a plausible effector region while preventing proprioceptive manifestation from counteracting it.

Finally, this framework has broad implications beyond the RHI. It suggests that body ownership is not a perceptual state arising from stable representations but an emergent property of motor-driven causal coupling. This reframing affects how we understand tool use, phantom limb phenomena, agency, motor disorders, and interactions between attention and action planning. By shifting the explanatory burden from multisensory integration to latent action trajectory architecture, the model provides a coherent foundation for revisiting classical embodiment research with a renewed ontological clarity.

In summary, the RHI does not constitute an illusion of the body but a mischaracterized window onto the underlying architecture of motor action. The phenomenon arises only when the natural causal connection between visual and proprioceptive domains is withheld. When this causal link is restored—as soon as motor intention emerges—the effect vanishes. This account resolves many inconsistencies in the existing literature and positions the RHI not as a failure of the system, but as a brief and entirely lawful configuration of the system's latent–manifest dynamics.

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