Musique, danse et neurones miroirs: l'exemple du tango

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Tango & Parkinson's: the studies

- *Short duration, intensive tango dancing for Parkinson disease: an uncontrolled study.* Hackney ME, Earhart GM. 2009
- *Randomized Controlled Trial of Community-Based Dancing Modify Disease Progression in Parkinson Disease.* Duncan RP, Earhart GM. Neurorehabil Neural Repair. 2011 Sep 29
Dance as therapy for individuals with Parkinson disease.
Here we demonstrate the impact of multi-year (average 16.5 years) amateur dancing (AD) in a group of elderly subjects (aged 65–84 years) as compared to education-, gender- and aged-matched controls (CG) having no record of dancing or sporting activities. Besides posture and balance parameters, we tested reaction times, motor behavior, tactile and cognitive performance. In each of the different domains investigated, the AD group had a superior performance as compared to the non-dancer CG group.
substantially better performance in the expert group than in the controls in terms of expertise-related domains like posture, balance, and reaction times. However, there was no generalization of positive effects to those domains that were found to be improved in amateur dancers, such as tactile and cognitive performance, suggesting that there might be an optimal range of intervention intensity to maintain health and independence throughout the human lifespan.
Effect of a Community-Based Argentine Tango Dance Program on Functional Balance and Confidence in Older Adults

Patricia McKinley, Allison Jacobson, Alain Leroux, Victoria Bednarczyk, Michel Rossignol, and Joyce Fung

Randomization by selecting envelopes containing group codes

Dropout
- n = 1
  - unrelated knee injury

Tango Group
- n = 14
  - 2 hours twice a week for 10 weeks
  - Evaluation T2: Post-Tango
  - Evaluation T3: Follow-up 1 month later

Walk Group
- n = 11
  - 2 hours twice a week for 10 weeks
  - Evaluation T2: Post-Walk
  - Evaluation T3: Follow-up 1 month later

Dropout
- n = 4
  - not receiving Tango

Assessment T1
Pre-Tango/Walk

Preliminary Screening
Telephone calls to respondents assessed by PT using the interRAI
n = 34

Introductory meeting
Signing of consent forms
n = 30

Evaluation T3
Follow-up
1 month later

Evaluation T2
Follow-up
1 month later

Evaluation T2
Follow-up
1 month later

Doing the tango improves the aging brain

The sultry moves of Argentine tango dancing can help the aging brain. McGill researchers have discovered that the fancy footwork required to perform the tango bolsters brainpower and improves balance.

With Canada’s growing aging population, this news is music to health professionals’ ears. About one-third of the elderly population in Canada experiences a fall each year and 40 percent of hospital admissions of this age group are due to fall-related injuries. Statistics show that 71 percent of seniors over the age of 65 live alone, and many spend more than seven hours a day without any social contact. This isolation, coupled with the normal aging process, can lead to cognitive decline.

This is where tango steps in. "Our findings suggest that tango may be better than walking for improving the execution of complex tasks and the ability to move within a restricted area without losing one’s footing," says McGill University School of Physical and Occupational Therapy Professor Patricia McKinley.

For the study, funded by the Drummond Foundation, researchers recruited 30 seniors from Cummings Jewish Senior Centre, aged 62 to 90. All were healthy individuals who had experienced a fall within the last year and had developed a fear of falling. Half the group was assigned to take tango lessons and the other half to a walking group. Each group met for two hours twice a week for ten weeks at the Constance Lehbridge Rehabilitation Centre. The tango group showed more improvement in balance, posture and motor coordination, as well as cognitive gains, than the walking group. They also performed significantly better than the walking group at performing a complex cognitive task while walking, standing on one foot, or turning in confined spaces.

Memory testing, however, was inconclusive, perhaps because the sample size was not large enough, says McKinley.

"Tango dancing is an ideal leisure activity for this population," says McKinley. "It satisfies three basic requirements for exercise adherence: it’s fun, it’s a group activity, and it has a tangible goal that can be perceived not only by the dancer, but by his or her family and friends."

Source: McGill University

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Mémoire de travail

Amélioration significative de la mémoire de travail dans les deux groupes

Attention divisée

Amélioration significative et persistante de l'attention divisée dans le groupe "tango"
Comment le tango peut-il améliorer le fonctionnement cérébral?

• Plusieurs explications avancées :
  – Général: le tango, comme l'aérobie, élève le rythme cardiaque d'environ 70% après une session de danse
  – Sensori-moteur:
    • Entraîne la marche dans directions multiples (avant arrière côté)
    • Favorise initiative du mouvement, entraîne l'impulsion et le transfert d'énergie
    • Stimule l'équilibre : travail de la posture dynamique et de l'équilibre seul et en couple
  – Cognitive/affective
    • Entraîne à exécuter des situations double-tâche : marcher tout en évitant des obstacles, anticiper la figure suivante, prendre en considération la position et les mouvements du partenaire
    • Largement basé sur la pratique de mouvements rythmés; nécessité de transcodage de l'information entre différentes modalités
    • Favorise les relations socio-affectives entre partenaires et entre les couples

Mais commun à beaucoup d'autres activités.

Mais commun à beaucoup d'autres danses.
THE NEUROSCIENCE OF DANCE

Recent brain-imaging studies reveal some of the complex neural choreography behind our ability to dance.

By Steven Brown and Lawrence M. Parsons

KEY CONCEPTS

- Dance is a fundamental form of human expression that likely evolved together with music as a way of generating rhythm.
- It requires specialized mental skills. One brain area houses a representation of the body's orientation, helping to direct our movements through space, another serves as a synchronization center, enabling us to pace our actions to music.
- Unconscious entrainment—the process that causes us to automatically tap our feet to a beat—reflects our instinct for dance. It occurs when certain subcortical brain regions become hyperactive higher auditory areas.
- The editors

So natural is our capacity for rhythm that most of us take it for granted. When we hear music, we tap our feet to the beat or nod or sway, often unaware that we are even moving. But this instinct is, for all intents and purposes, an evolutionary novelty among humans. Nothing comparable occurs in other mammals we probably nowhere in the animal kingdom. Our talent for unconscious entrainment lies at the core of dance, a confluence of movement, rhythm, and gestural representation, By far the most synchronized group practice, dance demands a type of interconnection and coordination in space and time that is absent or inconsistent in other social contexts.

Even though dance is a fundamental form of human expression, neuroscience has given it relatively little consideration. Recently, however, researchers have conducted the first brain-imaging studies of both amateur and professional dancers. These investigations address such questions as: How do dancers navigate though space? How do they pace their steps? How do people learn complex series of patterned movements? The results offer an intriguing glimpse into the complicated mental coordination required to execute even the most basic dance steps.

I Got Rhythm

Neuroscientists have long studied isolated movements such as ankle rotations or finger tapping. From this work we know the basics of how the brain orchestrates simple actions. To tap or to fore—never mind putting your hand at the same time—requires calculations related to spatial awareness, balance, tension and timing, among other things, in the brain's sensory-motor system. In a simplified version of the story, a region called the posterior parietal cortex (forward the base of the brain) translates visual information into motor commands, sending signals forward to motor-planning areas in the premotor cortex and supplementary motor area. These
TANTALIZING TANGO FINDING

In a study published in December 2007, Garrick M. Earhart and Madeleine H. Hackett of the Washington University School of Medicine in St. Louis found that tango dancing improved mobility in patients with Parkinson’s disease. The condition stems from a loss of neurons in the basal ganglia, a problem that interrupts messages meant for the motor cortex. As a result, patients experience tremors, rigidity and difficulty initiating movements they have planned. The researchers found that after 10 tango classes, study subjects “move” less often. Compared with subjects who attended an exercise class instead, the tango dancers also had better balance and higher scores on the last test and (on test, which identifies those at risk for falling.)

As anticipated, this comparison eliminated many of the basic motor areas of the brain. What remained, though, was a part of the parietal lobe, which contributes to spatial perception and orientation in both humans and other mammals. In dance, spatial cognition is primarily kinesthetic: you sense the positioning of your torso and limbs at all times, even with your eyes shut, thanks to the muscles’ sensory organs. These organs index the rotation of each joint and the tension in each muscle and relay that information to the brain, which generates an articulated body representation in response. Specifically, we saw activation in the precuneus, a parietal lobe region very close to where the kinesthetic representation of the leg resides. We believe that the precuneus contains a kinesthetic map that permits an awareness of body positioning in space while people navigate through their surroundings. Whether you are walking or simply walking a straight line, the precuneus helps to plot your path and does so from a body-centered or “egocentric” perspective.

Next we compared our dance scans to those taken while our subjects performed tango steps in the absence of music. By eliminating brain regions that the two tasks activated in common, we hoped to reveal areas critical for the synchronization of movement to music. Again this subtraction removed virtually all the brain’s motor areas. The principal difference occurred in a part of the cerebellum that receives input from the spinal cord. Although both conditions engaged this area—the anterior vermis—dance steps synchronized to music generated significantly more blood flow there than self-paced dancing did. Although preliminary, our result lends evidence...
Étude PET

• 10 sujets âge moy. : 33a
• 2.5a en moy d'expérience du tango argentin

Deux comparaisons :
• metric/non metric
• self paced/entrained

Trois conditions contrôle
• Listening (musique grecque)
• Constructions (avec musique)
• repos
Aire 44 droite ("anti-Broca") activée dans toutes les conditions motrices mais aussi dans tâches perceptives : "syntaxe supralinguistique?"

Circuit sous-cortical (MGN + cervelet) régule les aspects sensoriels de l'activité métrique ("beat")
Giacomo Rizzolatti

Single neuron recording
MIRROR NEURONS / BRAIN LOCALIZATION IN MONKEY AND MAN
Posterior edge of arcuate sulcus
= canonical neurons

Among classical
= general purpose
motor neurons

F5 convexity
= mirror neurons
Figure 2 | **Mirror neurons in area F5.** The recordings show neural discharges of a mirror neuron in area F5 of the macaque inferior frontal cortex when the monkey grasps food (top) and when the monkey observes the experimenter grasping the food (bottom)\(^\text{19}\). Note that both tasks elicit strong neural responses in area F5. Modified, with permission, from REF. 115 © (2001) Macmillan Publishers Ltd.
Hearing Sounds, Understanding Actions: Action Representation in Mirror Neurons

Evelyne Kohler,¹ Christian Keysers,¹ M. Alessandra Umlità,¹ Leonardo Fogassi,² Vittorio Gallese,¹ Giacomo Rizzolatti¹
In humans, as in monkey, there exists a system of mirror neurons involving a restricted set of cortical areas in two specific locations: ventral premotor and parietal
Mirror neurons differently encode the same gesture in two different contexts
Shared voxels in both action observation and action execution:

- dorsal premotor cortex (dPM) and ventral premotor cortex (vPM), which are involved in motor control;
- posterior mid-temporal gyrus (MTG), which is involved in visual perception;
- and a large cluster encompassing multiple regions of the parietal lobe

much of the parietal shared voxels actually fall into BA2, the association somatosensory cortex. This indicates that activity in this part of the cluster probably represents **vicarious haptic** activity instead of vicarious motor activity.
MODELS OF AGGRESSION Mirror neurons are at their best when humans are face to face. But at least one study found that the cells, along with several brain areas involved in aggression, were activated when children watched a violent television program. That activation increased the chances that the children would behave aggressively minutes or hours later.
Both of Us Disgusted in My Insula: The Common Neural Basis of Seeing and Feeling Disgust

Bruno Wicker,1 Christian Keysers,2,3 Jane Plailly,2 Jean-Pierre Royet,4 Vittorio Gallese,2 and Giacomo Rizzolati1,2,*

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leads to a proc state of disgust our decision n of the phenom resonance hy of another per sentation in tf review). This n

vision of disgust - neutral

overlapping vision & olfaction of disgust

disgusting odorant - rest

x=-40

x=-38

x=-36

x=-34

x=-32
Empathy for positive and negative emotions in the gustatory cortex

Mbemba Jabbi, a, b Marte Swart, a, c and Christian Keysers a, *
“Feeling” someone else’s pain...

Own pain:

Significant other’s pain:
Neural mechanisms of empathy in humans: A relay from neural systems for imitation to limbic areas

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Presentation of photographs of human faces representing 6 types of emotions (total face, mouth or eyes)

2 conditions: imitate/observe

Imitation and observation activate in common a network including premotor cortex and insula

Imitation > observation for right insula and IFG bilat.
En résumé (1): neurones miroir

• Il existe dans le cortex cérébral du singe, et sans doute également de l'homme, un sous-ensemble de neurones moteurs dont la caractéristique est de se mettre en activité tout autant lorsque l'individu effectue une action mais également lorsqu'il observe un autre individu effectuer la même action.

• Ce système est centré sur deux régions corticales : le cortex prémoteur postéro-inférieur (aire de Broca) et le cortex pariétal postérieur, deux régions de cortex associatif en interconnexion fonctionnelle réciproque étroite. D'autres régions auraient également un "fonctionnement miroir", en particulier l'insula, dont l'implication dans la perception des émotions d'autrui est actuellement bien établie, et le cortex somato-sensoriel primaire, qui traite l'ensemble des informations sensitives accompagnant nos actes, comme ceux d'autrui.

• Parmi les rôles suspectés chez l'homme de ce système : l'imitation et l'apprentissage par imitation, la compréhension des actions et des intentions d'autrui (théorie de l'esprit), l'acquisition du langage, les relations interpersonnelles et les compétences sociales, mais aussi : l'empathie, l'intersubjectivité, certains comportements violents …
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fMRI Results

Intraparietal sulcus

Dorsal premotor cortex

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Seeing or Doing? Influence of Visual and Motor Familiarity in Action Observation

Beatriz Calvo-Merino,¹,⁴ Julie Grèzes,² Daniel E. Glaser,¹ Richard E. Passingham,³,⁴ and Patrick Haggard¹,⁴

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that the network

Results

Observi
interaction between subject gender and performer gender
Comparison between observing video sequences of movements being learned (5h/week during 5 weeks) and non-learned movements. Then they must judge their capacity to perform the same movements (self-rating)

Activation of both parts of the mirror neuron system (IPS & IFG), especially if modulated by auto-evaluation

Rehearsed vs non rehearsed

Modulated by self-rating
IFG activations appear to reflect processes of music-syntactic analysis and working memory operations.

Widespread interconnections with both premotor cortex and limbic structures render it likely that the anterior superior insula plays a role in the activation of the Rolandic operculum during the emotional perception of the musical stimuli.

Comparison of active listening of pleasant and non-pleasant (electronically manipulated) musical extracts with fMRI: activation Heschl, ant-sup Insula and BA 45/46 (Broca).
Dynamic Emotional and Neural Responses to Music Depend on Performance Expression and Listener Experience

Frederic Chopin Etude in E major, Op.10, No. 3
("tristesse")

Expressive vs "mechanical" performance
a network of neural regions in the brain are activated in both an aural task (listening to piano melodies) and a motion-oriented task (‘playing’ a piano keyboard with no auditory output) in professional pianists, but this coactivation is not found in non-musicians.

The acoustic task (aT) required passively listening to 3-s monophonic piano sequences. In the motion-related task (mT), subjects were prompted to arbitrarily press keys on a soundless piano keyboard during a time window of 3 s.
Increased Gray Matter Volume of Left Pars Opercularis in Male Orchestral Musicians Correlate Positively With Years of Musical Performance

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Musicians (nb years)

Non-musicians (age)

Figure 5. Demonstration of POP (red) and PTR (green) on 3D views of left hemisphere in a musician (A) and a nonmusician (B).
Non-musicians trained to play simple melodies: activation of (mainly left) IFG when listening to learned melodies (compared to same notes unlearned).

Our findings thus support the view that Broca’s area is presumably a central region ("hub") of the mirror neuron network (Iacoboni et al., 1999; Nishitani and Hari, 2000; Hamzei et al., 2003; Rizzolatti and Craighero, 2004; Nelissen et al., 2005), demonstrating here its multifunctional role in action listening.
L'entraînement sensori-moteur et auditif (SA) améliore la discrimination de manière plus nette et provoque une MMN plus ample que l'entraînement auditif seul (A), tant pour la discrimination de mélodies que de rythmes.
En résumé (2) : danse, musique et neurones miroir

• L'étude de danseurs experts apporte un modèle privilégié de compréhension du fonctionnement du SNM et de son rôle dans l'apprentissage de gestuelles spécifiques à chaque danse
• Il existe un ensemble croissant et convergent d'arguments montrant que la perception de la musique mais aussi la capacité à jouer (et sans doute à apprendre à jouer) d'un instrument de musique fait appel de manière singulière au fonctionnement du système des neurones miroir (idéalement placé pour établir la jonction audio-motrice entre perception et production)
• Des expériences isolant l'aspect esthétique et le plaisir musicaux convergent vers l'activation spécifique de parties du SNM, en particulier l'insula et le gyrus frontal inférieur (''Broca''), deux zones dont la proximité anatomique suggère leur rôle conjoint mais distinct dans la façon dont l'humain perçoit et ''vit'' la musique
• Ainsi, perception, production et émotion musicales semblent étroitement liées par l'anatomie comme par la fonction
"The shared recruitment of this neural mechanism in both the sender and the perceiver of the musical message allows for co-representation and sharing of the musical experience."
A model of area F5 and the mirror-neurons system

Tango dansé : depuis la simulation sensori-motrice à l'intersubjectivité

- Perception (compréhension) du mouvement
- Perception de l'intention
- Partage de la sensation proprioceptive
- Simultanéité temporelle du mouvement
- Association audio-motrice (musique-danse)
- Résonance affective de la connexion danse/musique
- Résonance affective de l"abrazo" (proximité corporelle)
Empathie & intersubjectivité

Expérience réciproque de partage sensori-moteur
Effets non spécifiques

- Stimulation sensorimotrice non spécifique
- Sollicite la mémoire de travail
- Effet motivationnel positif
- Favorise la plasticité cérébrale par apprentissage nouvelles stratégies

Sollicitation spécifique du système des neurones-miroir

Possible effets spécifiques

- Stimule les mécanismes d'empathie
- Stimule les compétences sociales
- Favorise la synchronisation de systèmes neuronaux distincts (SNM, réseau de la cognition sociale…)
- Active les mécanismes de transcodage intermodal
- Stimule la connectivité

Effet hypothétique de la pratique du tango dansé sur le fonctionnement cognitif (e.g. chez le sujet âgé)
En conclusion,

- 1- La pratique du tango dansé améliore significativement certaines performances cognitives de sujets agés sains et atteints de troubles dégénératifs
- 2- La musique, comme la danse, font singulièrement appel à des circuits cérébraux superposables au système des neurones miroirs
- 3- Le tango, par ses caractéristiques rythmiques et sensoriomotrices, a toutes chances de solliciter massivement et de façon multiple le SNM
- 4- Stimuler le SNM a été proposé comme thérapeutique de diverses conditions liées au vieillissement comme au développement
Perspectives

• Utilisation de "tangothérapie" pour "entraîner" les neurones miroirs
  – Troubles liés à la sénescence : Parkinson, vieillissement normal et pathologique….
  – Troubles moteurs par lésions vasculaires focales
  – Troubles du développement
    • Autisme et trouble des interactions sociales
    • Autres : troubles développementaux du langage
    • Combinaison musique/danse