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## EDITORIAL

# Virtual reality, social intelligence, mirror neurons, and bipolar spectrum: a new perspective

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The first studies on treating social intelligence deficits through virtual reality were conducted in the field of attention deficit hyperactivity disorder.[1] The idea that virtual reality could simulate situations that required complex social interaction led to evidence that devices with immersive virtual reality may be excellent diagnostic tools for attention deficit hyperactivity disorder.[2,3]

Shortly thereafter, studies involving immersive virtual reality and brain imaging found that people diagnosed with bipolar disorder, even in euthymic phases, showed relevant social cognition deficits.[4,5] Social skills involve both cognitive and affective processing in "mentalization" (i.e., the ability to imagine and communicate mental states underlying behavior). The impairments have been found in both the critical and relapse phases, with the social intelligence deficit being considered a structural trait of bipolar disorder.[6-9]

Research using immersive virtual reality jointly with imaging techniques has shown that, when faced with emotional tasks/issues requiring cognitive processing and responses, the right anterior cingulate cortex, the insular cortex, and the inferior frontal cortex (i.e., the "mirror-neuron system") are activated in controls without bipolar disorder, while in those with bipolar disorder, activation of these brain areas is reduced.[4] The mirror-neuron system is essential for understanding the actions and behavior of others, as well as for awareness of one's own emotions and behavioral patterns.[10] Therefore, the mirror-neuron system is implicated in complex neurocognitive functions such as social cognition, theory of the mind, empathy, and language.[11]

When the first virtual reality-based cognitive remediation exercises in bipolar disorder were conducted, the researchers were aware of the fact that patients found traditional computer-based cognitive remediation boring, which could be the cause of high dropout rates among people with hyperactivation and novelty-seeking tendencies.[12] However, the results exceeded all expectations. Cognitive performance significantly improved in people with bipolar disorder who underwent a virtual reality-based cognitive remediation program.[13] Moreover, secondary analyses also showed improvement in residual depressive symptoms (an important element in relapse prevention)[14] and, above all and to a highly unexpected extent, a clear improvement in alexithymia.[13]

Although alexithymia has been considered a trait characteristic in the past[15] and, hence, difficult to modify, the above mentioned results are consistent with the hypothesis that virtual reality exercises can stimulate the mirror-neuron system through "bombardment" with similar real-world conditions. In fact, alexithymia is synonymous with poor awareness of one's emotional experiences and the ability to communicate emotional experiences (i.e., an ability closely linked to the mirror-neuron system).

Although it is not certain that improving alexithymia will improve the course of bipolar disorder, it is reasonable to expect improvement if we consider that, in bipolar disorder, the ability to recognize and communicate early symptoms is fundamental in preventing relapse.[16,17] A body of evidence indicates that early symptom recognition is an essential element in psychosocial interventions for both relapse and first onset prevention.[18,19]

When focusing on how improving alexithymia can prevent first onset among people at risk, it must be considered that, in recent surveys, socially adapted people without mood disorders but traits of hyperactivity and novelty seeking share a common genetic pattern with people who have bipolar disorder, i.e., such traits could be a potential area of vulnerability towards bipolar disorder, particularly during stress conditions.[20] Developing an effective tool against alexithymia could be important for this population, particularly since hyperstress can trigger bipolar disorder and symptom denial is a sort of maladaptive defense mechanism.[21]

From another point of view, these results lead to the hypothesis that bipolar disorder involves a pattern of neurocognitive response, which warrants analysis of the typical context of people with hyperactivity who are in the so-called "bipolar spectrum" according to the neo-Kraepelinian hypothesis. This spectrum ranges from hyperactive people without disorders to those with

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diagnosed bipolar disorder and, in the neo-Kraepelinian hypothesis, it would also include disorders such as attention deficit hyperactivity disorder. People in this spectrum would be characterized by a specific profile of emotional complexity analysis. Not examining emotional difficulties could be linked to a particular style of thinking that simplifies processes by erasing problems related to emotional issues, focusing instead on final objectives.

Episodes of sub-threshold hyperactivity were higher in samples of Sardinian emigrants in Latin America than in their compatriots in Sardinia.[22,23] Among these emigrants, adaptation difficulties and loss of affection were evidently less pressing (compared to those who remained) than the need to leave and achieve new goals. In this context, accelerated thinking about objectives could be a compensatory mechanism that is adaptive within certain limits.

In conclusion, working with virtual reality offers interesting perspectives for mood disorder prevention, in addition to clearer understanding of the mirror-neuron system and self-awareness.

## Disclosure

The authors report no conflicts of interest.

## Author contributions

MGC: Conceptualization, Formal analysis, Resources, Writing – original draft, Writing – review & editing.
AEN: Conceptualization, Formal analysis, Resources, Writing – original draft, Writing – review & editing.
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