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A Brief Overview of The Development of Body Representations Across Infancy, Childhood and Adulthood

Liam Alexander MacKenzie Myles [1]

[1] Department of Psychology, University of Cambridge, Cambridge, UK
E-mail corresponding author: liam.a.myles@outlook.com

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For centuries, philosophers have pondered over how bodies are represented as unitary entities and contemporary research is beginning to elucidate the answer. This paper will argue that different aspects of body representation develop at different rates across infancy and childhood, with body representation maturing to adult-like states by early adolescence. Firstly, the role of somatosensory cues will be outlined, before highlighting the influence of multisensory temporal and spatial congruity in body representation. A discussion of the early development of proprioceptive mechanisms will follow, before outlining the influence of peripersonal space in body representation. Finally, the role of top-down knowledge on body representation will be examined, clarifying the role of featural information in face representation.

Body representation (BR) refers to an individual's awareness and perception of their body. Both adults and infants exploit somatosensory cues in BR. For example, adults and 5-year-olds perceive that the distance between two points of tactile stimulation (TS) is larger in areas with greater tactile sensitivity (Le Cornu Knight et al., 2017). Further, 4-month-olds, but not 3-month-olds, exhibit contralateral neurological activity to the location of TS (Rigato et al., 2017; Somogyi et al., 2018). These findings suggest that both infants and adults utilise a topological representation of the body (Gillmeister et al., 2017), indicating that adults and infants exploit somatosensory cues in BR.

However, somatotopic BR appears to be modulated by limb localisation in adults. Evidence for this comes from the crossed-hands deficit (CHD), referring to the phenomenon that crossing one's hands impairs judgments regarding the temporal order of TS to both hands (Shore et al., 2002). This suggests that the limbs are automatically localised in the region of space with which they usually reside; consequently, reversing the locations of the hands impairs the localisation of TS. Indeed, children also automatically localise their limbs in external space. For example, 4-year-olds depict analogous CHDs to adults (Begum Ali et al., 2014) and similar deficits are present in 6-month-olds, but not 4-month-olds, when crossing their feet (Bremner et al., 2008). However, impairment in 6-month-olds ameliorates with visual input, suggesting that 6-month-olds expect somatosensory stimulation to be localised in the ipsilateral region of space, but that visual information supersedes these expectancies until early childhood (Pagel et al., 2009). Such expectancies may be dependent on early visual experience, as congenitally blind individuals who regain sight at 2 years fail to demonstrate a CHD (Ley et al., 2013; Roder et al., 2004). Therefore, both adults and infants utilise somatosensory cues in BR, with the localisation of somatosensory stimulation in exogenous space developing in the first 2 years of life.

Despite the role of somatotopy, adults utilise the temporal correspondence between sensory events to inform BR. The rubber hand illusion (RHI) demonstrates this phenomenon and entails eliciting simultaneous TS to the participant's occluded hand and a rubber hand (RH). Synchronous TS between their hand and the RH manifests embodiment, resulting in declarative ownership over the RH (Botvinick & Cohen, 1998). Adults also exhibit a shift in the perceived location of their index finger towards the RH after synchronous, but not asynchronous, TS; this implicit measure of embodiment is termed proprioceptive drift (PD). These findings elucidate the precedence of visual cues in reconciling contradictory visual and proprioceptive information into the perception of a unitary event (Chen et al., 2018), as exploiting proprioceptive cues would ameliorate the illusion.

Temporal contiguity between multisensory events also informs BR in young children. For example, the RHI induces illusory ownership in 4-year-olds and manifests greater PD during synchronous TS in 6-year-olds (Cowie et al., 2013). However, children aged 4-9 years exhibit greater PD, irrespective of synchrony, and reach adult-like levels by 11 years of age (Cowie et al., 2016); this highlights the precedence of visual cues during childhood, as sight of the RH can induce embodiment. However, congenitally blind, but not late blind, patients fail to exhibit illusory ownership during a somatosensory variant of the RHI (Nava et al., 2014). These findings suggest that early visual experience is necessary for the pre-eminence of visual stimulation over proprioceptive cues (Petkova et al., 2012).

Indeed, the differential developmental trajectories of visual-tactile and visual-proprioceptive mechanisms, as assessed through illusory ownership and PD, respectively, suggests that these processes develop separately (Cowie et al., 2016). Such mechanisms are rarely correlated (Nava et al., 2014) and the extended development of visual-proprioceptive mechanisms has been suggested to reflect the advantage of proprioceptive malleability during growth (Gori et al., 2008). For example, children exhibit greater proprioceptive errors in navigating their hands through narrow apertures than adults, implying proprioceptive malleability during childhood (De Haan et al., 2018; Hirtz & Starosta, 2002). Therefore, temporal contiguity between visual-tactile and visual-proprioceptive cues informs BR in an analogous manner to adults by 4 and 6 years of age, respectively, with visual-proprioceptive mechanisms continuing to develop into late childhood.

The role of temporal contiguity extends to full-body representation in both children and adults. For example, the full body illusion (FBI) entails viewing one's body through a head mounted display. Synchronous, but not asynchronous, TS applied to the posterior portion of one's own body induces illusory body ownership and PD in adults (Lenggenhager et al., 2007); PD reflects the localisation of one's body to be anterior to one's true location. Self-identification with the virtual body emerges by 6 years of age, reaching analogous magnitudes to adults at 11 years of age (Cowie et al., 2018). However, PD is not present until after 11 years of age, indicating that visual-proprioceptive mechanisms exhibit a latent development. This may reflect reduced peripersonal space (PPS) in children, referring to the proximal external space surrounding the body. Indeed, it has been suggested that objects must be within PPS to be embodied and that diminished PD during childhood reflects the relatively greater distance of the virtual body from the child's PPS (Bremner et al., 2014). Thus, temporal contiguity between multisensory stimuli entails a crucial role in adult BR and such mechanisms emerge by 6 years of age, developing throughout childhood.

Despite the protracted development of tactile-proprioceptive mechanisms, research indicates that proprioception influences infantile BR. For example, 3-month-olds display goal-oriented reaching behaviour towards visually occluded objects (Clifton et al., 1993) and foetuses demonstrate coordinated hand movements towards the mouth (Butterworth & Hopkins, 1988). These findings suggest that rudimentary proprioceptive mechanisms inform motor movements, and potentially BR, from birth. Additionally, infants also exploit tactile-proprioceptive correspondences in BR. For example, 7-month-olds preferentially look towards visual displays of legs receiving synchronous TS (Zmyj et al., 2011) and preferentially attend to legs with motor movements temporally contingent upon their own actions, compared to delayed motor movements (Schmuckler & Fairhall, 2001). However, preferential looking does not necessitate embodiment and one cannot assume that temporal congruence informs infantile BR in an analogous manner in adults (Bremner et al., 2012). Further, embodiment requires localisation of the stimulus in PPS; as visual displays are in extrapersonal space, preferential looking may not reflect embodiment (Bremner et al., 2014). Despite this, synchronous TS in a visual-proprioceptive task modulates temporal lobe activity, an area implicated in BR, in 5-month-olds in an analogous manner to adults, advocating the role of visual-proprioceptive correspondences in infantile BR (Filippetti et al., 2014; Leube et al., 2003). This suggests that rudimentary proprioception is available from birth and that visual-proprioceptive mechanisms inform BR by 5 months of age. However, subsequent research is required to clarify the role of visual-proprioceptive correspondences in infantile BR.

Spatial congruity between visual and proprioceptive stimulation is also crucial in BR and develops during early infancy. For example, adults report greater embodiment over virtual reality avatars when the avatar's movements are spatially contingent upon their own actions, as compared to spatially incongruent (Spanlang et al., 2014). Indeed, 5-month-olds preferentially attend to visual displays in which the directionality of their leg movements are reversed, suggesting that infants are also sensitive to the spatial congruity of visual-proprioceptive events (Bahrick & Watson, 1985). Preference for spatial incongruence has also been demonstrated in 3-month-olds (Rochat & Morgan, 1995), with evidence of additional motor activity during the incongruent condition. The authors postulated that preference for visual-proprioceptive spatial discrepancies may reflect exploration of novel relations between motor movements and visual feedback; this may consequently aid infantile BR (Bahrick, 2013). Indeed, preference for congruence develops by 9 months of age and may reflect embodiment over the stimulus, compared to preferential exploration of novelty (Hiraki, 2006). Thus, spatial congruity between visual and proprioceptive stimulation informs BR across the lifespan and may aid the construction of one's BR in the first 9 months of life.

Furthermore, the temporal and spatial disparity between cues that are integrated as unitary events declines during childhood. The temporal binding window (TBW) refers to the extent to which discrepant multisensory cues are perceived as unitary events (Wallace et al., 2004). Indeed, the TBW extends to the spatial domain and narrows from childhood to adulthood. For example, 8-year-olds perceive visual displays to be contingent upon their own actions at greater delays than adults (Jaime et al., 2014) and, when shown virtual hands, 5-year-olds report analogous locations between the virtual and real hand at greater spatial discrepancies than adults (Greenfield et al., 2017). Moreover, performance improved on both tasks across childhood, reaching adult-like levels by 11 years of age. Associative learning and prediction error mechanisms may underpin such phenomena (Myles, 2021a, 2021b; Myles & Merlo, 2022b). These findings suggest that perceptions of temporal and spatial congruity reach maturity by early adolescence, with children integrating more discrepant cues into unitary sensory events than adults.

In addition to multisensory mechanisms, top-down 'knowledge' also influences BR. Reductions in structural (Tsakiris & Haggard, 2010) and textural (Haans et al., 2008) similarity between the RH and true hand result in declinations of illusory ownership during the RHI, suggesting that top-down knowledge mediates the influence of multisensory congruence on embodiment. Top-down knowledge also informs infantile BR, with evidence that 10-month-olds preferentially look at rubber legs, compared to wooden blocks, during synchronous TS (Zmyj et al., 2011). Three-month-olds also preferentially attend to intact, compared to scrambled, bodies (Zieber et al., 2015) and exhibit modulated event-related potentials in response to intact body stimuli (Gliga & Dehaene-Lambertz, 2005). These findings suggest that infants also possess knowledge regarding normal body configurations.

Despite the early development of top-down mechanisms, body size representation is immature during infancy. For example, 17-month-olds often fail to account for body size and make errors such as attempting to navigate through impassable apertures (Franchak & Adolph, 2012). Such errors decline from 18 months to 26 months of age (Brownell et al., 2007), suggesting that experiential use of one's body informs body size representation. This continues to develop across childhood and, by 6 years of age, children exhibit greater implicit and explicit embodiment of RHs with congruent postures during synchronous TS (Gottwald et al., 2018). Indeed, adults are highly sensitive to discontinuities between visual and proprioceptive postural information, as minor deviations in the orientation of the RH from the real hand extensively diminishes illusory ownership (Costantini & Haggard, 2007). Thus, both adults and infants utilise top-down knowledge in BR and such mechanisms mature across infancy and childhood.

As previously alluded to, PPS is another top-down mechanism influencing BR from infancy. For example, the RHI does not occur in adults when the hand is largely spatially discrepant from the body (Lloyd, 2007). Whilst sparse, there is some evidence that infants represent PPS in a similar manner to adults. For example, 8-month-olds utilise postural changes to extend their reach towards a goal object (McKenzie et al., 1993) and estimations of whether an object is within one's reach become adult-like by 5 years of age (Gabbard et al., 2007). Adults exhibit modifications of PPS when using tools, such that the hand's PPS undergoes a transient augmentation (Farnè & Làdavas, 2000). Specifically, the representation of space around the hands of participants was increased subsequent to tool use. Seven-year-olds also demonstrate analogous reach estimations to adults when considering the extent to which a tool will increase their reach (Caçola & Gabbard, 2012). Therefore, evidence suggests that PPS representations manifest by 8 months of age and mature during early childhood, however further research is required regarding the developmental trajectory of PPS.

Contemporary literature suggests that the role of multisensory cues in embodiment varies between body parts. 'Enfacement' refers to the manifestation of illusory ownership over a face during synchronous, but not asynchronous, TS (Sforza et al., 2010). Participants also demonstrate implicit enfacement, stating that pictures of their face entail integrated features of the stimulus-face, and exhibit impaired recognition of their face, suggesting that enfacement extends the categorical representation of one's face (Tajadura-Jimenez et al., 2012). However, explicit reports of enfacement entail reductions in negative ratings of ownership and often fall below affirmative scores (Beck et al., 2015). This suggests that face representation (FR) is only modestly malleable through multisensory stimulation.

Moreover, recent evidence indicates analogous enfacement in infants. For example, neonates preferentially observe faces with temporally and spatially congruent, as compared to incongruent, TS (Filippetti et al., 2013) and 5-month-olds exhibit modulated temporoparietal junction activity in response to TS (Filippetti et al., 2014), an area implicated in self-identification (Apps et al., 2013). However, such studies often delay visual feedback in the asynchronous condition; asynchronous stimulation is consequently predictive of TS, potentially resulting in partial enfacement. Removal of such confounds in studies utilising adult populations results in greater embodiment during synchronous, compared to asynchronous, TS (Bufalari et al., 2014), suggesting that estimations of enfacement in infants may be modest. Despite this, FR matures in early infancy and multisensory cues are ostensibly less influential in the representation of faces than other body parts in adulthood.

Indeed, FR is highly dependent on knowledge regarding featural information. For example, the 'rouge test' assesses self-recognition and involves orienting one's behaviour towards a blemish on one's face (Bertenthal & Fischer, 1978). Despite a 3-minute delay in visual-feedback, 4-year-olds reach for the blemish (Povinelli et al., 1996), suggesting that recognition is independent of multisensory integration. Indeed, 5-month-olds preferentially look towards a static image of a peer's face, compared to their own, demonstrating knowledge of their facial appearance (Legerstee et al., 1998). Infants often pass the rouge test by 18 months of age (Nielson et al., 2003), however those that fail preferentially look towards their own face during synchronous TS (Filippetti & Tsakiris, 2018). The authors speculated that the infants were utilising multisensory congruency to construct a feature-based representation of their face (Miyazaki & Hiraki, 2006). Indeed, multisensory mechanisms may 'update' feature representation in adulthood, due to incremental changes in appearance (Porciello et al., 2018). Thus, whilst multisensory integration may aid the construction of one's FR during infancy and update featural representations in adulthood, FR is predominantly feature-based.

In conclusion, despite the availability of somatotopic mechanisms during early infancy, multisensory mechanisms appear to inform BR from early childhood and continue to mature into late childhood. Visual-proprioceptive mechanisms entail a protracted developmental trajectory, however rudimentary proprioceptive abilities are available from birth and may be utilised in BR. Indeed, the temporal and spatial binding window declines across childhood, reaching adult-like states by early adolescence. However, top-down knowledge regarding form, texture and PPS may mediate the influence of multisensory cues on BR, with FR more heavily dependent on featural information than multisensory information. Thus, BR consists of multiple mechanisms that develop at varying rates across infancy and childhood, reaching adult-like states by adolescence. Future research should continue to examine the development of BR and also related clinical pathology (Frisone et al., 2021; Merlo et al., 2022; Myles & Merlo, 2021), as such difficulties can have drastic ramifications on both physical and mental health (Gugliandolo et al., 2020; Myles & Merlo, 2022a; Myles et al., 2020; Myles et al., 2021).

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Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any potential conflict of interest.

References

1. Apps, M. A., Tajadura-Jiménez, A., Sereno, M., Blanke, O., & Tsakiris, M. (2013). Plasticity in unimodal and multimodal brain areas reflects multisensory changes in self-face identification. *Cerebral Cortex, 25(1),* 46-55. https://doi.org/10.1093/cercor/bht199
2. Bahrick, L. E. (2013). Body perception: Intersensory origins of self and other perception in newborns. *Current Biology, 23(23),* 1039-1041. https://doi.org/10.1016/j.cub.2013.10.060
3. Bahrick, L. E., & Watson, J. S. (1985). Detection of intermodal proprioceptive–visual contingency as a potential basis of self-perception in infancy. *Developmental Psychology, 21(6),* 963–973. https://doi.org/10.1037/0012-1649.21.6.963
4. Beck, B., Cardini, F., Làdavas, E., & Bertini, C. (2015). The enfacement illusion is not affected by negative facial expressions. *PloS one, 10(8),* e0136273. https://doi.org/10.1371/journal.pone.0136273
5. Begum Ali, J., Cowie, D., & Bremner, A. J. (2014). Effects of posture on tactile localization by 4 years of age are modulated by sight of the hands: evidence for an early acquired external spatial frame of reference for touch. *Developmental Science, 17(6),* 935-943. https://doi.org/10.1111/desc.12184
6. Bertenthal, B. I., & Fischer, K. W. (1978). Development of self-recognition in the infant. *Developmental Psychology, 14(1),* 44–50. https://doi.org/10.1037/0012-1649.14.1.44
7. Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature, 391(6669),* 756-756. https://doi.org/10.1038/35784
8. Bremner, A. J., Ali, J. B., & Cowie, D. (2014). The origins of ability and automaticity in tactile spatial perception. *Developmental science, 6(17),* 946-947.
9. Bremner, A. J., Holmes, N. P., & Spence, C. (2012). The development of multisensory representations of the body and of the space around the body. *Multisensory development,* 113-136. https://doi.org/10.1093/acprof:oso/9780199586059.003.0005
10. Bremner, A. J., Mareschal, D., Lloyd-Fox, S., & Spence, C. (2008). Spatial localization of touch in the first year of life: Early influence of a visual spatial code and the development of remapping across changes in limb position. *Journal of Experimental Psychology: General, 137(1),* 149–162. https://doi.org/10.1037/0096-3445.137.1.149
11. Brownell, C. A., Zerwas, S., & Ramani, G. B. (2007). "So big": The development of body self-awareness in toddlers. *Child development, 78(5),* 1426-1440. https://doi.org/10.1111/j.1467-8624.2007.01075.x
12. Bufalari, I., Lenggenhager, B., Porciello, G., Serra Holmes, B., & Aglioti, S. M. (2014). Enfacing others but only if they are nice to you. *Frontiers in behavioral neuroscience, 8,* 102. https://doi.org/10.3389/fnbeh.2014.00102
13. Butterworth, G., & Hopkins, B. (1988). Hand-mouth coordination in the new-born baby. *British Journal of Developmental Psychology, 6(4),* 303-314. https://doi.org/10.1111/j.2044-835X.1988.tb01103.x
14. Caçola, P., & Gabbard, C. (2012). Modulating peripersonal and extrapersonal reach space via tool use: a comparison between 6-to 12-year-olds and young adults. *Experimental brain research, 218(2),* 321-330. https://doi.org/10.1007/s00221-012-3017-8

15. Chen, Y. C., Lewis, T. L., Shore, D. I., Spence, C., & Maurer, D. (2018). Developmental changes in the perception of visuotactile simultaneity. *Journal of experimental child psychology, 173,* 304-317. https://doi.org/10.1016/j.jecp.2018.04.014
16. Clifton, R. K., Muir, D. W., Ashmead, D. H., & Clarkson, M. G. (1993). Is visually guided reaching in early infancy a myth? *Child development, 64(4),* 1099-1110. https://doi.org/10.1111/j.1467-8624.1993.tb04189.x
17. Costantini, M., & Haggard, P. (2007). The rubber hand illusion: sensitivity and reference frame for body ownership. *Consciousness and cognition, 16(2),* 229-240. https://doi.org/10.1016/j.concog.2007.01.001
18. Cowie, D., Makin, T. R., & Bremner, A. J. (2013). Children's responses to the rubber-hand illusion reveal dissociable pathways in body representation. *Psychological Science, 24(5),* 762-769. https://doi.org/10.1177/0956797612462902
19. Cowie, D., McKenna, A., Bremner, A. J., & Aspell, J. E. (2018). The development of bodily self-consciousness: changing responses to the Full Body Illusion in childhood. *Developmental science, 21(3),* e12557. https://doi.org/10.1111/desc.12557
20. Cowie, D., Sterling, S., & Bremner, A. J. (2016). The development of multisensory body representation and awareness continues to 10 years of age: evidence from the rubber hand illusion. *Journal of experimental child psychology, 142,* 230-238. https://doi.org/10.1016/j.jecp.2015.10.003
21. De Haan, A. M., Smit, M., Van der Stigchel, S., Keyner, S. A., & Dijkerman, H. C. (2018). Body representation does not lag behind in updating for the pubertal growth spurt. *Journal of experimental child psychology, 175,* 48-66. https://doi.org/10.1016/j.jecp.2018.05.002
22. Farnè, A., & Làdavas, E. (2000). Dynamic size-change of hand peripersonal space following tool use. *Neuroreport, 11(8),* 1645-1649.
23. Filippetti, M. L., & Tsakiris, M. (2018). Just Before I Recognize Myself: The Role of Featural and Multisensory Cues Leading up to Explicit Mirror Self-Recognition. *Infancy, 23(4),* 577-590. https://doi.org/10.1111/infa.12236
24. Filippetti, M. L., Johnson, M. H., Lloyd-Fox, S., Dragovic, D., & Farroni, T. (2013). Body perception in newborns. *Current Biology, 23(23),* 2413-2416. https://doi.org/10.1016/j.cub.2013.10.017
25. Filippetti, M. L., Lloyd-Fox, S., Longo, M. R., Farroni, T., & Johnson, M. H. (2014). Neural mechanisms of body awareness in infants. *Cerebral Cortex, 25(10),* 3779-3787. https://doi.org/10.1093/cercor/bhu261
26. Franchak, J. M., & Adolph, K. E. (2012). What infants know and what they do: Perceiving possibilities for walking through openings. *Developmental Psychology, 48(5),* 1254–1261. https://doi.org/10.1037/a0027530
27. Frisone, F., Sicari, F., Settineri, S., & Merlo, E. M. (2021). Clinical psychological assessment of stress: a narrative review of the last 5 years. *Clinical Neuropsychiatry, 18*(2), 91-100. https://doi.org/10.36131/cnfioritieditore20210203
28. Gabbard, C., Cordova, A., & Ammar, D. (2007). Estimation of reach in peripersonal and extrapersonal space: a developmental view. *Developmental Neuropsychology, 32(3),* 749-756. https://doi.org/10.1080/87565640701539451

29. Gillmeister, H., Bowling, N., Rigato, S., & Banissy, M. J. (2017). Inter-individual differences in vicarious tactile perception: a view across the lifespan in typical and atypical populations. *Multisensory Research, 30(6),* 485-508.
30. Gliga, T., & Dehaene-Lambertz, G. (2005). Structural encoding of body and face in human infants and adults. *Journal of Cognitive Neuroscience, 17(8),* 1328-1340. https://doi.org/10.1162/0898929055002481
31. Gori, M., Del Viva, M., Sandini, G., & Burr, D. C. (2008). Young children do not integrate visual and haptic form information. *Current Biology, 18(9),* 694-698. https://doi.org/10.1016/j.cub.2008.04.036
32. Gottwald, J. M., Bird, L., Keenaghan, S., Diamond, C., Zampieri, E., Tosodduk, H., & Cowie, D. (2018). The developing bodily self: Posture constrains embodiment in children and adults.
33. Greenfield, K., Ropar, D., Themelis, K., Ratcliffe, N., & Newport, R. (2017). Developmental changes in sensitivity to spatial and temporal properties of sensory integration underlying body representation. *Multisensory Research, 30(6),* 467-484.
34. Gugliandolo, M. C., Costa, S., Cuzzocrea, F., Larcan, R., & Martino, G. (2020). Adolescents and body uneasiness: the contribution of supportive parenting and trait emotional intelligence. *Journal of Child and Family studies, 29*(9), 2453-2462. https://doi.org/10.1007/s10826-020-01779-1
35. Haans, A., IJsselsteijn, W. A., & de Kort, Y. A. (2008). The effect of similarities in skin texture and hand shape on perceived ownership of a fake limb. *Body Image, 5(4),* 389-394. https://doi.org/10.1016/j.bodyim.2008.04.003
36. Hiraki, K. (2006). Detecting contingency: A key to understanding development of self and social cognition. *Japanese Psychological Research, 48(3),* 204-212. https://doi.org/10.1111/j.1468-5884.2006.00319.x
37. Hirtz, P., & Starosta, W. (2002). Sensitive and critical periods of motor co-ordination development and its relation to motor learning. *Journal of Human Kinetics, 7,* 19-28.
38. Jaime, M., Longard, J., & Moore, C. (2014). Developmental changes in the visual–proprioceptive integration threshold of children. *Journal of experimental child psychology, 125,* 1-12. https://doi.org/10.1016/j.jecp.2013.11.004
39. Le Cornu Knight, F., Cowie, D., & Bremner, A. J. (2017). Part-based representations of the body in early childhood: evidence from perceived distortions of tactile space across limb boundaries. *Developmental science, 20(6),* e12439. https://doi.org/10.1111/desc.12439
40. Legerstee, M., Anderson, D., & Schaffer, A. (1998). Five-and eight-month-old infants recognize their faces and voices as familiar and social stimuli. *Child Development, 69(1),* 37-50. https://doi.org/10.1111/j.1467-8624.1998.tb06131.x
41. Lenggenhager, B., Tadi, T., Metzinger, T., & Blanke, O. (2007). Video ergo sum: manipulating bodily self-consciousness. *Science, 317(5841),* 1096-1099. https://doi.org/10.1126/science.1143439
42. Leube, D. T., Knoblich, G., Erb, M., Grodd, W., Bartels, M., & Kircher, T. T. (2003). The neural correlates of perceiving one's own movements. *Neuroimage, 20(4),* 2084-2090. https://doi.org/10.1016/j.neuroimage.2003.07.033

43. Ley, P., Bottari, D., Shenoy, B. H., Kekunnaya, R., & Röder, B. (2013). Partial recovery of visual–spatial remapping of touch after restoring vision in a congenitally blind man. *Neuropsychologia, 51(6),* 1119-1123. https://doi.org/10.1016/j.neuropsychologia.2013.03.004

44. Lloyd, D. M. (2007). Spatial limits on referred touch to an alien limb may reflect boundaries of visuo-tactile peripersonal space surrounding the hand. *Brain and cognition, 64(1),* 104-109. https://doi.org/10.1016/j.bandc.2006.09.013

45. McKenzie, B. E., Skouteris, H., Day, R. H., Hartman, B., & Yonas, A. (1993). Effective action by infants to contact objects by reaching and leaning. *Child Development, 64(2),* 415-429. https://doi.org/10.1111/j.1467-8624.1993.tb02918.x

46. Merlo, E., Pappalardo, S., & Myles, L. (2022). The VESPA Project: Virtual Reality Interventions for Neurocognitive and Developmental Disorders. *Journal of Mind and Medical Sciences, 9*(1), 16-27. https://doi.org/10.22543/7674.91.P1627

47. Miyazaki, M., & Hiraki, K. (2006). Delayed intermodal contingency affects young children's recognition of their current self. *Child Development, 77(3),* 736-750. https://doi.org/10.1111/j.1467-8624.2006.00900.x

48. Myles, L. (2021a). The Emerging Role of Computational Psychopathology in Clinical Psychology. *Mediterranean Journal of Clinical Psychology, 9*(1). https://doi.org/10.6092/2282-1619/mjcp-2895

49. Myles, L. (2021b). Using Prediction Error to Account for the Pervasiveness of Mood Congruent Thoughts. *Mediterranean Journal of Clinical Psychology, 9*(2). https://doi.org/10.13129/2282-1619/mjcp-3130

50. Myles, L., & Merlo, E. (2021). Alexithymia and physical outcomes in psychosomatic subjects: a cross-sectional study. *Journal of Mind and Medical Sciences, 8*(1), 76-85. https://scholar.valpo.edu/jmms/vol8/iss1/12

51. Myles, L., & Merlo, E. (2022a). Incongruities between Perceived Control and Desire for Control: A Mechanistic Account of Depression in Adolescence. *Psychiatria i Psychologia Kliniczna, 22*(1), 40-44. https://doi.org/10.15557/PiPK.2022.0005

52. Myles, L., & Merlo, E. (2022b). Elucidating the Cognitive Mechanisms Underpinning the Therapeutic Efficacy of Behavioural Activation. *International Journal of Psychological Research, 15*(1), 126-132. https://doi.org/10.21500/20112084.5400

53. Myles, L., Connolly, J., & Stanulewicz, N. (2020). The Mediating Role of Perceived Control and Desire for Control in the Relationship between Personality and Depression. *Mediterranean Journal of Clinical Psychology, 8*(3). https://doi.org/10.6092/2282-1619/mjcp-2589

54. Myles, L., Merlo, E., & Obele, A. (2021). Desire for Control Moderates the Relationship between Perceived Control and Depressive Symptomology. *Journal of Mind and Medical Sciences, 8*(2), 229-305. https://doi.org/10.22543/7674.82.P299305

55. Nava, E., Steiger, T., & Röder, B. (2014). Both developmental and adult vision shape body representations. *Scientific reports, 4,* 6622. https://doi.org/10.1038/srep06622

56. Nielsen, M., Dissanayake, C., & Kashima, Y. (2003). A longitudinal investigation of self–other discrimination and the emergence of mirror self-recognition. *Infant Behavior and Development, 26(2),* 213-226. https://doi.org/10.1016/S0163-6383(03)00018-3

57. Pagel, B., Heed, T., & Röder, B. (2009). Change of reference frame for tactile localization during child development. *Developmental science, 12(6),* 929-937. https://doi.org/10.1111/j.1467-7687.2009.00845.x
58. Petkova, V. I., Zetterberg, H., & Ehrsson, H. H. (2012). Rubber hands feel touch, but not in blind individuals. *PloS one, 7(4),* e35912. https://doi.org/10.1371/journal.pone.0035912
59. Porciello, G., Bufalari, I., Minio-Paluello, I., Di Pace, E., & Aglioti, S. M. (2018). The 'Enfacement'illusion: A window on the plasticity of the self. *Cortex, 104,* 261-275. https://doi.org/10.1016/j.cortex.2018.01.007
60. Povinelli, D. J., Landau, K. R., & Perilloux, H. K. (1996). Self-recognition in young children using delayed versus live feedback: Evidence of a developmental asynchrony. *Child development, 67(4),* 1540-1554. https://doi.org/10.1111/j.1467-8624.1996.tb01813.x
61. Rigato, S., Banissy, M. J., Romanska, A., Thomas, R., van Velzen, J., & Bremner, A. J. (2017). Cortical signatures of vicarious tactile experience in four-month-old infants. *Developmental cognitive neuroscience, 35*, 75-80. https://doi.org/10.1016/j.dcn.2017.09.003
62. Rochat, P., & Morgan, R. (1995). Spatial determinants in the perception of self-produced leg movements in 3-to 5-month-old infants. *Developmental Psychology, 31(4),* 626. https://doi.org/10.1037/0012-1649.31.4.626
63. Röder, B., Rösler, F., & Spence, C. (2004). Early vision impairs tactile perception in the blind. *Current Biology, 14(2),* 121-124. https://doi.org/10.1016/j.cub.2003.12.054
64. Schmuckler, M. A., & Fairhall, J. L. (2001). Visual-proprioceptive intermodal perception using point light displays. *Child Development, 72(4),* 949-962. https://doi.org/10.1111/1467-8624.00327
65. Sforza, A., Bufalari, I., Haggard, P., & Aglioti, S. M. (2010). My face in yours: Visuo-tactile facial stimulation influences sense of identity. *Social neuroscience, 5(2),* 148-162. https://doi.org/10.1080/17470910903205503
66. Shore, D. I., Spry, E., & Spence, C. (2002). Confusing the mind by crossing the hands. *Cognitive Brain Research, 14(1),* 153-163. https://doi.org/10.1016/S0926-6410(02)00070-8
67. Somogyi, E., Jacquey, L., Heed, T., Hoffmann, M., Lockman, J. J., Granjon, L., & O'Regan, J. K. (2018). Which limb is it? Responses to vibrotactile stimulation in early infancy. *British Journal of Developmental Psychology, 36(3),* 384-401. https://doi.org/10.1111/bjdp.12224
68. Spanlang, B., Normand, J. M., Borland, D., Kilteni, K., Giannopoulos, E., Pomés, A., & Slater, M. (2014). How to build an embodiment lab: achieving body representation illusions in virtual reality. *Frontiers in Robotics and AI, 1,* 9. https://doi.org/10.3389/frobt.2014.00009
69. Tajadura-Jiménez, A., Grehl, S., & Tsakiris, M. (2012). The other in me: interpersonal multisensory stimulation changes the mental representation of the self. *PloS one, 7(7),* e40682. https://doi.org/10.1371/journal.pone.0040682
70. Tsakiris, M., Longo, M. R., & Haggard, P. (2010). Having a body versus moving your body: neural signatures of agency and body-ownership. *Neuropsychologia, 48(9),* 2740-2749. https://doi.org/10.1016/j.neuropsychologia.2010.05.021
71. Wallace, M. T., Roberson, G. E., Hairston, W. D., Stein, B. E., Vaughan, J. W., & Schirillo, J. A. (2004). Unifying multisensory signals across time and space. *Experimental Brain Research, 158(2),* 252-258. https://doi.org/10.1007/s00221-004-1899-9

72. Zieber, N., Kangas, A., Hock, A., & Bhatt, R. S. (2015). Body structure perception in infancy. *Infancy, 20(1),* 1-17. https://doi.org/10.1111/infa.12064

73. Zmyj, N., Jank, J., Schütz-Bosbach, S., & Daum, M. M. (2011). Detection of visual–tactile contingency in the first year after birth. *Cognition, 120(1),* 82-89. https://doi.org/10.1016/j.cognition.2011.03.001

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