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Byrne, Ailish and Preston, Catherine orcid.org/0000-0001-7158-5382 (2019) Mr Fantastic Meets The Invisible Man : An Illusion of Invisible Finger Stretching. Perception. ISSN 0301-0066

https://doi.org/10.1177/0301006618821068

Mr Fantastic meets the Invisible Man: An illusion of Invisible Finger Stretching

Our brain continually integrates bottom-up sensory signals to create a coherent experience of the body. This bodily experience is also constrained by top-down knowledge of body appearance. However, the extent of these constraints has been challenged. Here we explore top-down limits on body ownership with the invisible finger stretching illusion, in which synchronous visuotactile stimulation applied to the real fingers and an area of empty space elicits the illusion of owning elongating fingers. The results demonstrate it is possible to experience stretchy fingers like Mr Fantastic without visual stimuli of a fake hand, even if we don't actually feel invisible like The Invisible Man.

Mr Fantastic from The Fantastic Four can stretch his body beyond what is physically possible, whereas The Invisible Man can walk around unseen with light passing straight through his body. Fictional comic book characters often achieve impossible feats with the human body. But are these physically impossible bodies actually possible to experience in the human brain? The rubber hand illusion (Botvinick & Cohen, 1998), in which ownership over the fake hand is induced by synchronously touching the seen fake hand and the hidden real hand, demonstrates the importance of multisensory integration for body ownership. Top-down constraints governing bodily experience have also been identified, which prevent feelings of ownership (opposed to embodiment for tool-use, de Vignemont, 2011) over non-corporal objects (Tsakiris, Carpenter, James, & Fotopoulou, 2010). However, the extent to which appearance constrains body ownership has been challenged. We can experience different size and shaped bodies as our own, including invisible hands (Guterstam, Gentile, & Ehrsson, 2013) and comic book style elongated limbs (Preston & Newport, 2011; Preston & Newport, 2012). However, such stretching illusions typically use sophisticated technology to provide realistic visual feedback, which may not be necessary. This study (approved by the University of York Psychology ethics committee) further examined the extent of top-down constraints on body ownership by testing an invisible finger stretching (IFS) illusion, in which synchronous visuotactile stimulation applied to the real fingers and an area of empty space elicits an illusion of elongating invisible fingers (Figure 1).

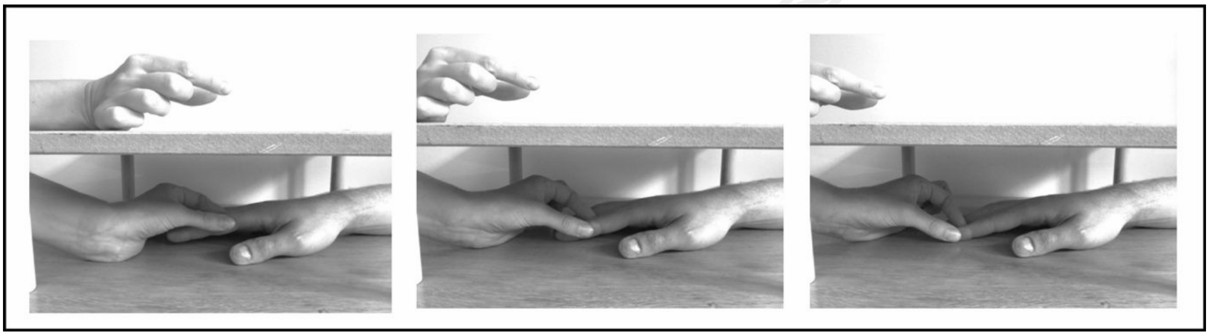
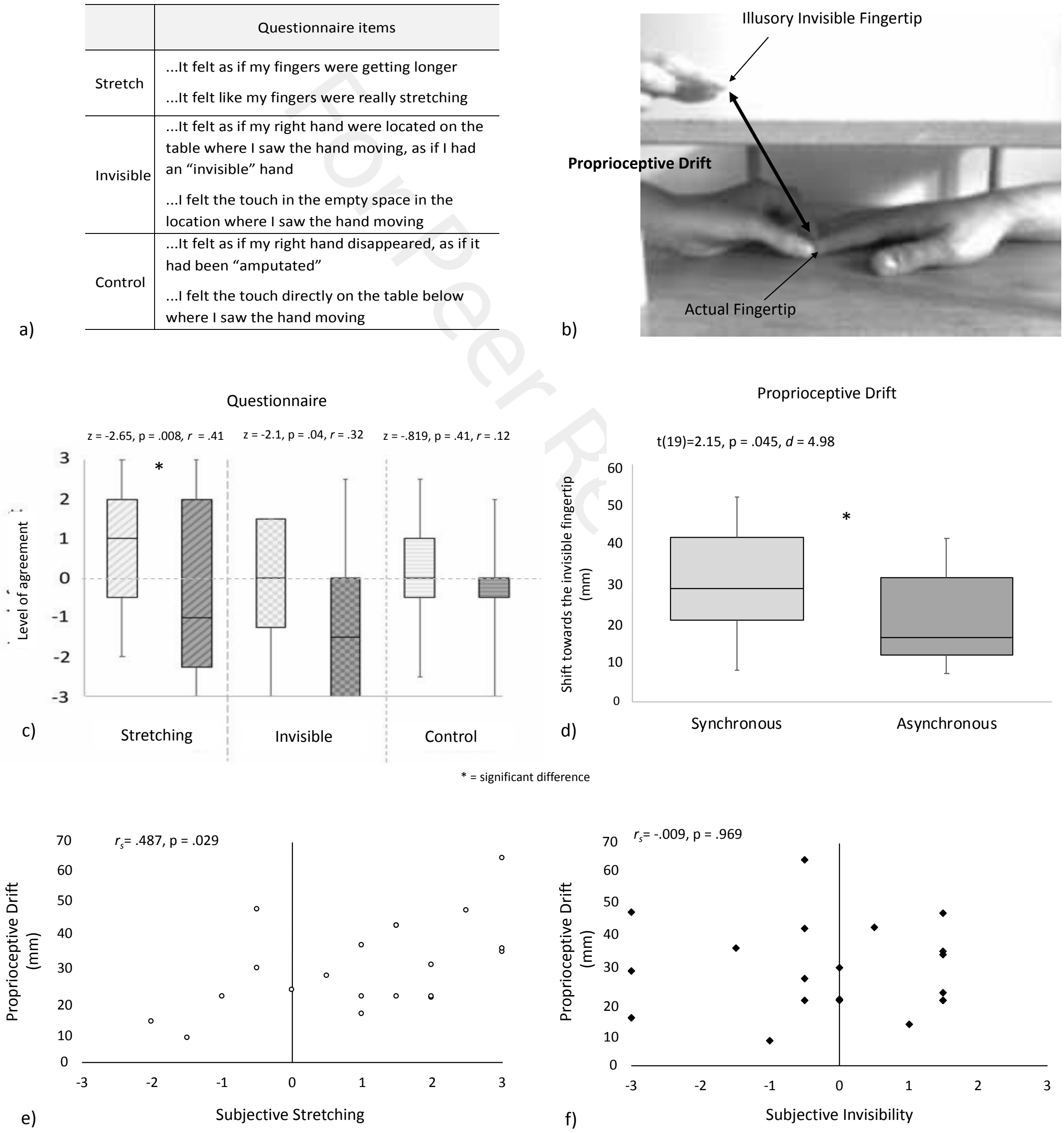


Figure 1: Participants' **(N = 21, 1M; 2 left handed; mean age = 19)** **right hand was hidden** **in a fixed location** **underneath a wooden platform** **with a cape covering their forearm (shoulder to wrist). In each 60s trial (2 per condition) the experimenter consecutively gripped the base of each finger (not the thumb)** **with her thumb and index finger and gently pulled whilst sliding her grip to the fingertip** **(~1Hz with ~1s between each stimulation).** **At the same time she synchronously or asynchronously mimicked identical actions in empty space above the platform at a faster velocity extending beyond the**

length of the actual hand (depicted above left to right). Pulling tactile stimulation (Newport et al., 2015) was implemented to elicit feelings of the fingers stretching rather than simply owning longer fingers.

The IFS illusion successfully manipulated perceived finger length (Figure 2). However, participants didn't agree that their hand felt invisible (median = 0) and stretching but not invisibility correlated with proprioceptive drift. These results extend previous findings that we can experience ownership over a volume of empty space equivalent to the real hand size (Guterstam et al., 2013), and that we retain ownership over illusory stretched (visible) fingers (Newport et al., 2015).



a)

	Questionnaire items
Stretch	...It felt as if my fingers were getting longer ...It felt like my fingers were really stretching
Invisible	...It felt as if my right hand were located on the table where I saw the hand moving, as if I had an "invisible" hand ...I felt the touch in the empty space in the location where I saw the hand moving
Control	...It felt as if my right hand disappeared, as if it had been "amputated" ...I felt the touch directly on the table below where I saw the hand moving

Figure 2: The invisible finger stretch illusion was measured with questionnaire responses (a) and proprioceptive drift (in separate trials), for which participants pointed to the felt position of the index finger before and after stimulation. Participants were asked to

consider both lateral and vertical information in their judgement (b). Following synchronous touch, participants felt like their fingers were stretching (Bonferroni critical p = .016) (c) and judged the position of their right fingertip as closer to the illusory elongated fingertip compared to asynchronous touch (data from 1 participant excluded due to recording error) (d). These effects were not found for control questions or for questions asking about perceived hand invisibility (c). In the synchronous conditions, proprioceptive drift correlated with feelings of stretching (e) but not invisibility (f).

Feeling ownership over hands that we cannot see is an everyday occurrence and may underpin the experience of the invisible hand illusion (Guterstam et al., 2013). Indeed, full-body illusions using virtual reality suggest body transparency inhibits ownership (Martini, Kilteni, Maselli, & Sanchez-Vives, 2015). Alternatively, the illusion of elongating fingers may have just been a more salient experience and thus distracted participants' from hand invisibility. Although stretchy fingers are also impossible, throughout life our bodies generally get bigger. Accordingly, it has been demonstrated that we can feel greater ownership over larger compared to smaller fake hands (Pavani & Zampini, 2007) and legs (Romano, Llobera, & Blanke, 2016), which may suggest that our body representation is particularly adaptable to increases in body size. Although perceptual reductions in body size have been observed using full-body illusions, in which naturalistic body proportions are maintained (Preston & Ehrsson, 2014).

We know that our brains are continually integrating sensory signals to create a coherent experience of the body and that this bodily experience is constrained by top-down knowledge of body appearance. However, it seems that despite these constraints our brain's representation of our body is highly adaptable, to the extent that we can experience stretchy fingers like Mr Fantastic without direct vision of the body, even if we don't actually feel invisible like The Invisible Man.

Botvinick, M., & Cohen, J. (1998). Rubber hands "feel" touch that eyes see. *Nature*, *391*(6669), 756. http://doi.org/10.1038/35784

de Vignemont, F. (2011). Embodiment, ownership and disownership. *Consciousness and Cognition*, *20*(1), 82–93. http://doi.org/https://doi.org/10.1016/j.concog.2010.09.004

Guterstam, A., Gentile, G., & Ehrsson, H. H. (2013). The Invisible Hand Illusion : Multisensory Integration Leads to the Embodiment of a Discrete Volume of Empty Space. *Journal of Cognitive Neuroscience*, *25*(7), 1078–1099. http://doi.org/10.1162/jocn

Martini, M., Kilteni, K., Maselli, A., & Sanchez-Vives, M. V. (2015). The body fades away: investigating the effects of transparency of an embodied virtual body on pain threshold and body ownership. *Scientific Reports*, *5*, 13948. http://dx.doi.org/10.1038/srep13948

Newport, R., Auty, K., Carey, M., Greenfield, K., Howard, E. M., Ratcliffe, N., Thair, H., Themelis, K. (2015). Give It a Tug and Feel It Grow: Extending Body Perception Through the Universal Nature of Illusory Finger Stretching. *I-Perception*, *6*(5), 2041669515599310. http://doi.org/10.1177/2041669515599310

Pavani, F., & Zampini, M. (2007). The role of hand size in the fake-hand illusion paradigm. *Perception*, *36*(10), 1547–1554. http://doi.org/10.1068/p5853

Preston, C., & Ehrsson, H. H. (2014). Illusory Changes in Body Size Modulate Body Satisfaction in a Way That Is Related to Non-Clinical Eating Disorder Psychopathology. *PLOS ONE*, *9*(1), e85773. https://doi.org/10.1371/journal.pone.0085773

Preston, C., & Newport, R. (2011). Analgesic effects of multisensory illusions in osteoarthritis. *Rheumatology*, *50*(12). http://doi.org/10.1093/rheumatology/ker104

Preston, C., & Newport, R. (2012). How Long is Your Arm? Using Multisensory Illusions to Modify Body Image from the Third Person Perspective. *Perception*, *41*(2), 247–249. http://doi.org/10.1068/p7103

Romano, D., Llobera, J., & Blanke, O. (2016). Size and Viewpoint of an Embodied Virtual Body Affect the Processing of Painful Stimuli. *The Journal of Pain*, *17*(3), 350–358. http://doi.org/https://doi.org/10.1016/j.jpain.2015.11.005

Tsakiris, M., Carpenter, L., James, D., & Fotopoulou, A. (2010). Hands only illusion: multisensory integration elicits sense of ownership for body parts but not for non-corporeal objects. *Experimental Brain Research*, *204*(3), 343–352. http://doi.org/10.1007/s00221-009-2039-3

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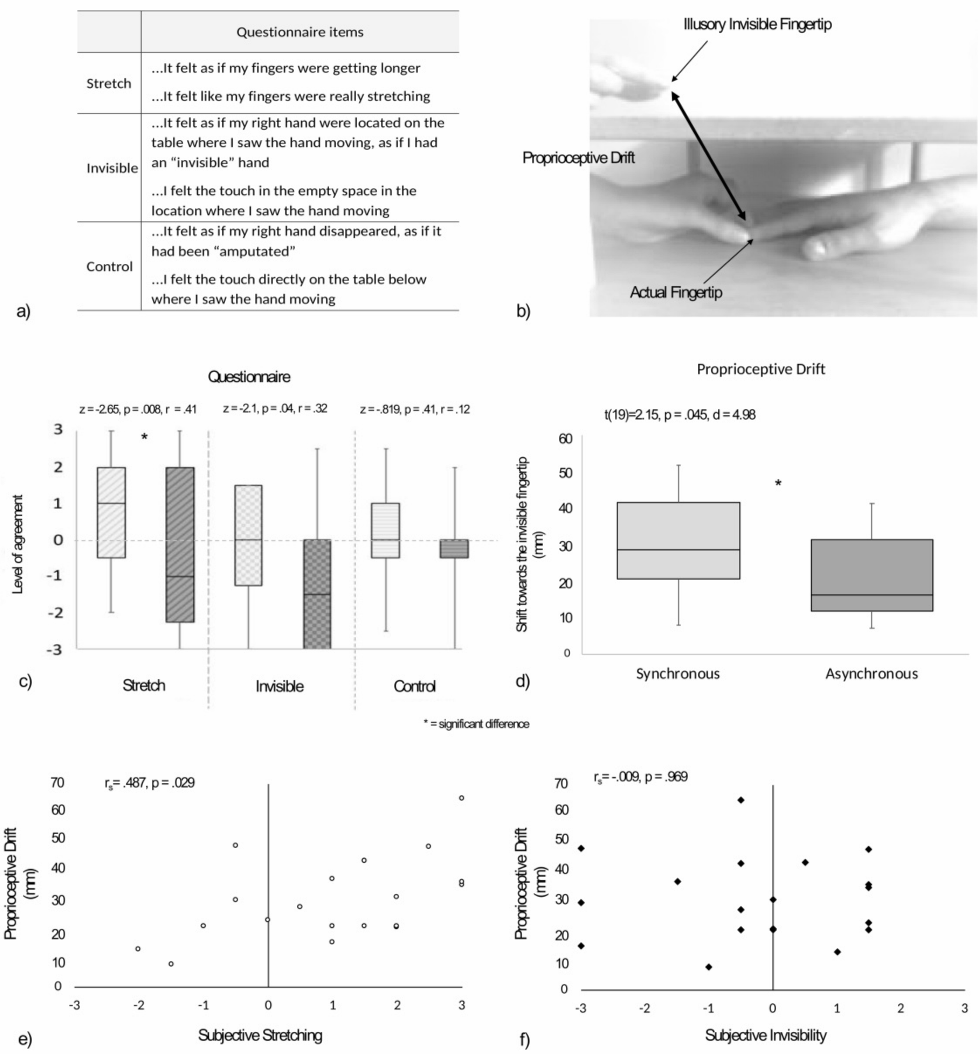

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