
SHORT AND SWEET

A new method for assessing self-touch enhancement of the foot in stroke patients with mobility problems

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Abstract. Patient NG is the first reported case of lower-limb ‘self-touch enhancement’ following stroke. Mobility problems prevented NG from reaching to touch her foot, thus we used a self-touch rubber-hand paradigm to mimic the conditions of self-administered touch. With vision precluded, NG administered stimulation to a prosthetic limb while the Examiner administered synchronous stimulation to NG’s affected left foot. NG detected all stimulation administered with our self-touch paradigm, whereas in the control condition (with NG not involved in administering stimulation), NG had failed to detect one-third of Examiner-administered stimulation. When mobility problems are a barrier to investigating self-touch enhancement, the self-touch paradigm can be used to demonstrate residual tactile sensation following stroke.

Keywords: body representation, rubber-hand illusion, self-touch, sensation, stroke

Stroke patients with a sensory impairment may not detect touch administered by another person but they may detect touch of the same intensity when it is self-administered. This phenomenon, termed ‘self-touch enhancement’ (STE), has been investigated in five studies. Self-touch enhancement can occur when the patient administers self-touch without Examiner assistance (van Stralen et al 2011) and when the patient is guided by the Examiner to administer touch (Valentini et al 2008; Weiskrantz and Zhang 1987; White et al 2010a, 2010b). Possible explanations for how STE occurs include: (1) *proprioceptive information*, the patient infers touch based on the relative position of the patient’s administering hand and the affected body part; (2) *spatial attention*, the patient’s administering hand provides a spatial cue that directs attention toward the affected body part; (3) *temporal expectation*, the action of the patient’s administering hand provides a temporal cue that focuses attention as touch is administered. Although there is no reason to presume that STE is limited to the upper limbs, all five previous studies have focused on the hands. Methodological ease is the most likely explanation. Self-administering touch to the lower limbs (particularly the feet) can be challenging, if not impossible, when stroke patients have mobility problems. We describe a simple paradigm that overcomes these problems.

NG is a 21-year-old female, who experienced a right-hemisphere stroke resulting in left hemiplegia. (For full details of NG’s neuropsychological assessment, see White et al 2010a, 2010b.) At 3½ months after stroke NG’s motor function had improved, but she had problems with sensation in her left foot. Whereas individuals without sensory impairment detect stimulations of 0.07 g intensity with a Semmes–Weinstein monofilament, NG did not detect ⅓ of Examiner-administered stimulations of 15 g intensity to the left foot. We set out to assess STE using a self-touch rubber-hand paradigm because NG could not comfortably reach her left foot to administer self-touch.

In the self-administered-stimulation condition (with and without localisation cues; see table 1), the Examiner guided NG's right hand, which held the Semmes–Weinstein monofilament, to administer stimulation to a prosthetic hand positioned on NG's lap. The Examiner administered synchronous stimulation to the dorsal surface of the toes of NG's left foot using a Semmes–Weinstein monofilament of 15 g intensity (see figure 1: top panel). The procedure was demonstrated to NG prior to testing, thus NG was aware that she was administering stimulation to a prosthetic hand and receiving stimulation to her foot. NG wore a blindfold during testing, so that her responses were based on tactile rather than visual information. After each trial, the Examiner asked NG whether she had detected touch to her foot and whether she could localise the touch to a specific toe. There were three conditions—an Examiner-administered condition and two self-administered conditions. Each condition comprised 60 trials: 10 stimulations to each toe, and an additional 10 *sham* trials to ensure reliability of responses. On sham trials in the Examiner-administered-stimulation condition, no stimulation was administered by the Examiner to NG's foot. On sham trials in the two self-administered-stimulation conditions (with or without localisation cues), no stimulation was administered by the Examiner to NG's foot, but NG's right hand (guided by the Examiner) administered stimulation to the prosthetic hand. It was important to prevent NG from noticing which trials were sham trials (eg by the presence or absence of rustling sounds from the Examiner's clothing). Thus, for sham trials in all three conditions, the Examiner carried out the actions for administering stimulation, but paused when the tip of the monofilament was 1–2 cm from NG's foot.

Table 1. Three conditions for the assessment of self-touch enhancement.

Condition	Procedure	Task
1 Examiner-administered stimulation	Examiner administered stimulation to foot	(a) report if touch was detected (yes/no) (b) report where touch was detected (1–5; 1 = big toe, 5 = little toe)
2 Self-administered stimulation <i>with</i> localisation cues	Examiner administered stimulation to foot, while guiding NG's right hand, which held the Semmes–Weinstein monofilament, to administer stimulation to the spatially analogous digit of the prosthetic hand (eg if Examiner administered stimulation to NG's big toe then NG administered stimulation to the thumb of the prosthetic hand)	as above
3 Self-administered stimulation <i>without</i> localisation cues	Examiner administered stimulation to foot, while guiding NG's right hand, which held the Semmes–Weinstein monofilament, to administer stimulation to the back of the prosthetic hand. Because NG administered stimulation to the same location (back of the prosthetic hand) on each trial, this condition allowed us to rule out the possibility that NG used subtle (leftward and rightward) movements of her administering hand to help her with detection and/or localisation	as above

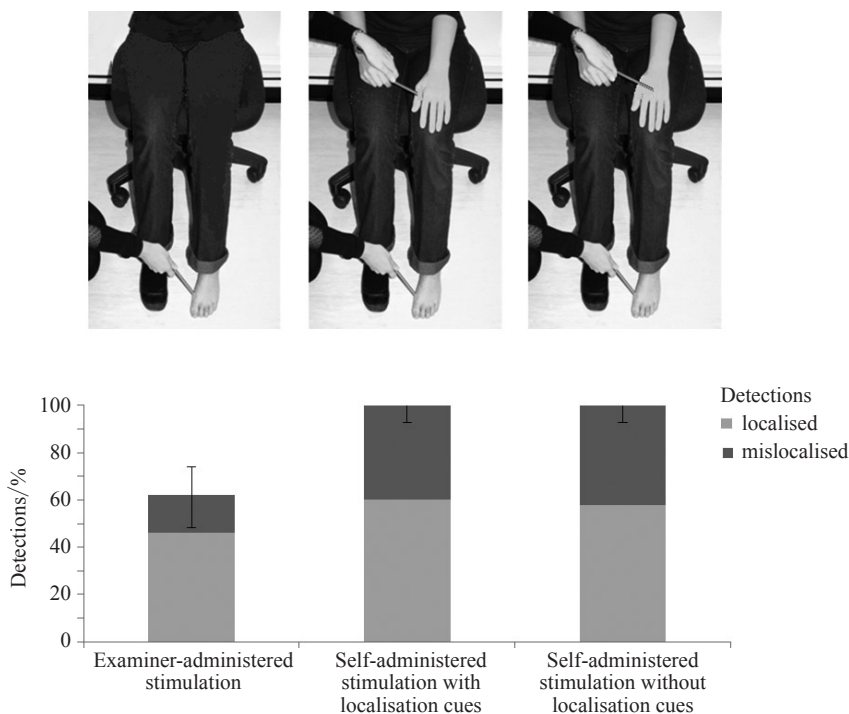


Figure 1. Top panel: Experimental set-up for three stimulation-administration conditions. Bottom panel: Localised and mislocalised detections in each experimental condition. Error bars represent 95% Wilson Confidence Intervals.

Analyses were conducted with the Q' test (Michael 2007), used in single-case analyses to test the hypothesis of equal proportions. First, we assessed for STE, that is, better detection of self-administered stimulation compared to Examiner-administered stimulation. Second, we assessed for differences in stimulus *localisation*, that is, correct report of which toe was stimulated.

NG demonstrated STE (figure 1: bottom panel). Although NG detected only 31/50 Examiner-administered stimulations, she detected 50/50 self-administered stimulations with localisation cues, and 50/50 self-administered stimulations without localisation cues [$Q'(1) = 18.61$, $p < 0.0001$]. Crucially, NG did not report touch on any of the sham trials. Thus, it is not that NG reported touch each time she carried out the actions for self-administered stimulation. Instead, NG reported touch only when self-administered stimulation coincided with the Examiner's stimulation of her affected left foot.

There were no significant differences found for accuracy, when localising which toe was stimulated, in the three experimental conditions (Examiner-administered = 23/31, 74% correctly localised; self-administered with localisation cues = 30/50, 60% correctly localised; self-administered without localisation cues = 29/50, 58% correctly localised; all p values > 0.196). The task of localising stimulation on the toes is notoriously difficult (Halnan and Wright 1960) even for individuals without a sensory impairment. It is thus not surprising that NG mislocalised a large proportion of stimulations. More important is the finding that NG was not 'guessing' about the location of felt touch, and that she must have had some information about location of stimulation because 87.76% of mislocalisations were to the neighbouring toe.

When NG administered stimulation to a prosthetic hand while the Examiner administered synchronous stimulation to her foot, NG may have experienced the illusion of a single self-touch event (Ramachandran and Hirstein 1997). According to a Bayesian explanation, there is

a low probability that the action of NG's hand and the sensation on her foot could correspond so precisely by chance. Thus it may have seemed to NG that she was administering touch directly to her foot. Notably, this 'illusion of self-touch' can *only* be elicited if the participant has sensation in the receptive body part (White et al 2010b).

NG is the first published case of 'lower limb' STE following stroke. Residual sensation in her left foot was demonstrated with a paradigm that was designed to overcome the mobility problems that prevented NG from touching her foot. NG administered stimulation to a prosthetic hand (positioned on her lap) and received stimulation to her affected left foot (positioned on the ground). Because the administering hand and affected foot were never in contact with each other, STE cannot be explained by (1) NG using proprioceptive information to infer touch or (2) NG's attention being directed by spatial cues from the administering hand. Instead, the findings support the temporal expectation hypothesis (White et al 2010b): the action of NG's administering hand provided a temporal cue that focused attention as touch was administered.

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