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Effect of meaning on apraxic finger imitation deficits

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ABSTRACT

Apraxia typically results from left-hemispheric (LH), but also from right-hemispheric (RH) stroke, and often impairs gesture imitation. Especially in LH stroke, it is important to differentiate apraxia-induced gesture imitation deficits from those due to co-morbid aphasia and associated semantic deficits, possibly influencing the imitation of meaningful (MF) gestures. To explore this issue, we first investigated if the 10 supposedly meaningless (ML) gestures of a widely used finger imitation test really carry no meaning, or if the test also contains MF gestures, by asking healthy subjects ($n=45$) to classify these gestures as MF or ML. Most healthy subjects (98%) classified three of the 10 gestures as clearly MF. Only two gestures were considered predominantly ML.

We next assessed how imitation in stroke patients (255 LH, 113 RH stroke) is influenced by gesture meaning and how aphasia influences imitation of LH stroke patients ($n=208$). All patients and especially patients with imitation deficits (17% of LH, 27% of RH stroke patients) imitated MF gestures significantly better than ML gestures. Importantly, meaningfulness-scores of all 10 gestures significantly predicted imitation scores of patients *with* imitation deficits. Furthermore, especially in LH stroke patients *with* imitation deficits, the severity of aphasia significantly influenced the imitation of MF, but not ML gestures.

Our findings in a large patient cohort support current cognitive models of imitation and strongly suggest that ML gestures are particularly sensitive to detect imitation deficits while minimising confounding effects of aphasia which affect the imitation of MF gestures in LH stroke patients.

1. Introduction

Apraxia is a disorder of motor cognition which most often occurs after left hemisphere (LH) stroke (Donkervoort et al., 2000), but has also been reported after right hemisphere (RH) stroke (Donkervoort et al., 2000; Goldmann Gross and Grossman, 2008).

Apraxia is characterized by a bilateral impairment of purposeful, skilled movements, including imitation. Importantly, as a higher motor deficit apraxia cannot be fully accounted for by primary deficits of the sensorimotor system or disturbed communication (Dovern et al., 2012). Tests of gesture imitation are frequently used for the (bed-side) assessment of apraxia (Goldenberg, 2008). However, it remains a challenge to differentiate whether an observed imitation deficit is due to apraxia or results from (often co-morbid) aphasia and associated semantic deficits when meaningful (MF) gestures have to be imitated (Goldenberg, 2008). Accordingly, for diagnosing apraxic imitation deficits, tests which employ meaningless (ML) gestures are recommended, since ML gestures are supposed to be unfamiliar/novel and hence should not be represented in long-term memory (Goldenberg, 1996; Mengotti et al., 2013). Current cognitive models of gesture imitation suggest that ML (unfamiliar/novel) gestures need to be processed via a direct (non-semantic) route without access to action semantics, while MF (familiar) gestures can also be reproduced via an indirect (semantic) route accessing pre-existing motor representations and action semantics (Cubelli et al., 2000; Rothi et al., 1991; Rumiati and Tessari, 2002). Note that the direct route is termed “direct” as it bypasses semantic processing. It should be stressed that this does not exclude other cognitive processes like deployment of attention, visuo-spatial transformations, or body part coding (Goldenberg, 2008).

Two imitation tests devised by Goldenberg are commonly used

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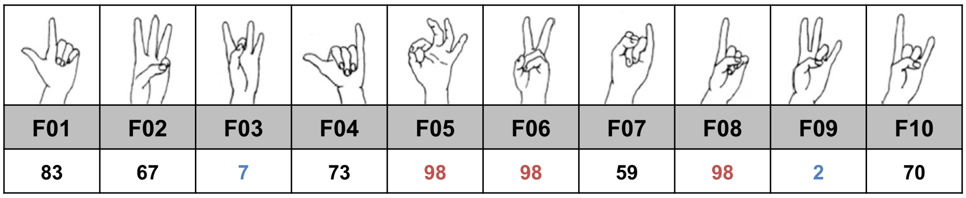

Fig. 1. The 10 finger gestures of the imitation test.
Graphical representation of the 10 finger gestures (adapted from Goldenberg (1996)), in the order F01 to F10, in which they are presented during testing used in the test of imitating finger configurations adopted from Goldenberg (1996). The meaning score (i.e., the relative proportion of healthy subjects (expressed in percent) who rated a given finger gesture as meaningful (MF, see Methods) is given below each finger gesture. Three finger gestures (F05, F06 and F08) were classified as MF by almost all (98%) healthy participants. In contrast, two finger gestures (F03 and F09) were classified meaningless (ML), since they were rated as MF by only 7% (F03) and 2% (F09) of the healthy subjects. The remaining five finger configurations (F01, F02, F04, F07 and F10) were classified as MF by 59% to 83% of the 45 healthy subjects.
Reprinted with permission (obtained from Elsevier publisher) from Goldenberg, G., Laimgruber, K., and Hermsdörfer, J. (2001) Imitation of gestures by disconnected hemispheres. *Neuropsychologia*, *39*(13), 1432–1443.

to assess gesture imitation in stroke patients (Goldenberg, 1996): the imitation of hand positions and the imitation of finger configurations. The gestures used in both tests are supposed to be ML, i.e., unfamiliar/novel gestures. While this is not questioned for the test of imitating hand positions, it is unclear whether all finger configurations used in the finger imitation test are truly ML. For example, finger configurations F01, F02, F06 and F08 (see Fig. 1) correspond to counting gestures that are known to activate number knowledge in healthy adults (for review, see (Fischer and Brugger, 2011). To address this important concern, we here investigated the effect of meaning on finger imitation deficits in a large cohort of stroke patients ($n=368$), thereby probing current cognitive models of gesture imitation which were based on much smaller patient samples (e.g., Cubelli et al., 2000; Mengotti et al., 2013; Tessari et al., 2007). Furthermore, the current investigation sheds light on the finger imitation test, which has a special standing within the diagnostics of limb apraxia, since-in contrast to most other commonly used limb apraxia tests (e.g., hand imitation)-the finger imitation test seems to be sensitive not only to imitation deficits after damage to the motor-dominant left hemisphere, but also to deficits resulting from right hemisphere damage (Goldenberg et al., 2009; Goldenberg and Strauss, 2002).

To this end, we first assessed whether healthy subjects ($n=45$) classified the 10 finger gestures of the Goldenberg finger imitation test (Goldenberg, 1996) as ML or MF. We next evaluated, retrospectively, in 255 patients with LH stroke and 113 patients with RH stroke whether their imitation performance of these finger gestures was influenced by meaning. We found that only two of the 10 gestures were perceived as clearly ML and that meaningfulness improved imitation scores of apraxic patients. Furthermore, the severity of aphasic deficits in LH stroke patients significantly influenced their imitation of MF gestures. Our results have implications for the diagnosis of imitation deficits and for theoretical models of gesture imitation.

2. Material and methods

2.1. The test of imitating finger configurations

In the test of imitating finger configurations by Goldenberg (1996), the examiner sits opposite to the patient and demonstrates each finger gesture (in the order F01–F10, see Fig. 1) with the hand opposite to the patient's non-paretic ipsilesional hand, which the patient is supposed to use for imitation. After the first demonstration of each finger gesture, the examiner forms a fist (neutral gesture) and the patient is asked to imitate the previously shown finger gesture. Two points are allocated for correct imitation. If the imitation is incorrect, the examiner repeats the demonstration of the finger gesture and then returns to the neutral gesture (fist). The patient is asked to imitate the finger gesture once more. One point is allocated for correct imitation in this second trial. If the patient fails to correctly imitate the finger gesture on both attempts, no point is allocated. Note that the examiner is supposed to judge only the end position of the finger gesture; self-corrections or hesitations during the process of imitating do not influence the assessment. A patient is considered to suffer from a finger imitation deficit if the total imitation score for the 10 finger gestures is 16 or less of the 20 possible points (10 gestures $\times$ two points each).

2.2. Assessing the effect of meaning on stroke patients' finger gesture imitation

In order to analyse the effect of meaning on stroke patients' finger gesture imitation, the 10 gestures of the finger imitation test by Goldenberg (see Fig. 1) were first presented to 45 healthy subjects (mean age: 50 ± 21 years; i.e., comparable to the mean age of the patient sample (see 2.3.), 59% female). Participants were asked whether these 10 finger gestures were MF to them or not (ML). Since gestures are considered to be MF if they are familiar/known (Tessari and Rumiati, 2004), subjects were asked whether they were familiar with/knew a given finger gesture or whether the gesture was unfamiliar/novel to them. This procedure is in accordance with the definition of the terms “meaningless” (ML) and “meaningful” (MF) by Goldenberg: “Meaningless gestures do not form part of the repertoire of habitual gestures and are hence essentially novel.” (Goldenberg, 2008).

Note that it was stressed to the subjects that they should not feel forced to come up with a specific meaning of a given finger gesture, but that they should rather indicate if they had seen that finger gesture before in a meaningful context (e.g., as a sign; cf. finger gesture F06, Fig. 1). In other words, subjects were not required to actively designate a specific meaning to a given finger gesture (e.g., they did not need to state that the finger gesture F06 can be used as the ‘victory’ or ‘peace’ sign). Finger gestures that were not rated as familiar (i.e., MF) by the healthy subjects were classified as ML. If participants were not sure whether they were familiar with a given finger gesture or whether it was novel to them, they were allowed to rate this gesture as neutral (i.e., “I do not know”).

For each finger gesture, the relative proportion of healthy subjects who rated this gesture as familiar (i.e., MF) was expressed in percent. This percentage score served to represent the meaningfulness of each finger configuration (meaning score). This assessment of the finger gestures' meaning in healthy subjects revealed that three finger gestures (F05, F06 and F08, Fig. 1) were classified as MF by almost all (98%) healthy participants. Accordingly, we classified these three finger gestures as clearly MF. Two finger gestures (F03 and F09, Fig. 1) were mostly considered ML,