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Research report

Apraxia of object-related action does not depend on visual feedback

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ABSTRACT

Pantomime of tool use is typically affected in neurological patients with apraxia, while at the same time these patients are able to perform the use of the actual tool with less or no errors. This discrepancy is commonly explained by differences in afferent input, in particular a lack of visual online feedback from the object in pantomime. The present study investigated the role of visual feedback in apraxia of pantomime by testing neurological patients with apraxia and healthy controls in a task requiring the pantomime of tool use as well as real tool use. Visual feedback was systematically removed at different phases of the action using shutter glasses that were controlled online based on real-time motion-capturing. Data analyses revealed more errors in pantomime than in real tool use. These differences were similar in patients as well as in controls. Removal of visual feedback did not affect apractic errors specifically; it neither increased patients' apractic errors during pantomime of tool use nor transformed the patients' normal movements with a real tool into movements with apractic errors. Our findings contradict the hypothesis that apraxia patients pathologically over-rely on visual feedback. Instead, we propose that pantomime of tool use requires cognitive processes that are not necessary for real tool use and independent of visual online feedback.

1. Introduction

Apraxia is a common behavioural consequence of vascular or neurodegenerative defects primarily to the left hemisphere. It is defined as a disorder of higher skilled movements not caused by primary motor or sensory disturbances (Heilman & Rothi, 1993). Patients with apraxia struggle in different action-related tasks, as for example pantomime of tool use (Bartolo,

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Daumüller, Sala, & Goldenberg, 2007; Clark, Merians, & Kothari, 1994; Goldenberg & Hagmann, 1998; Goldenberg et al., 2007; Goldenberg, Hartmann, & Schlott, 2003; Jarry et al., 2013; Liepmann, 1908), imitation and execution of meaningful or meaningless gestures (De Renzi, Motti, & Nichelli, 1980; Goldenberg, 1996; Goldenberg, 2011; Liepmann, 1908; Mengotti, Ripamonti, Pesavento, & Rumiati, 2015; Rumiati, Carmo, & Corradi-Dell'Acqua, 2009), motor imagery (Buxbaum, Johnson-Frey, & Bartlett-Williams, 2005; Ochipa et al., 1997), or mechanical reasoning (Baumard, Osiurak, Lesourd, & LeGall, 2014; Goldenberg & Hagmann, 1998) (for reviews see Wheaton & Hallett, 2007; Goldenberg, 2011). Surprisingly, patients with apraxia of pantomime (hereinafter simply referred to as 'apraxia') often fail to pantomime the use of a tool, i.e. to imitate grip, body posture, and movements as if they held and use the tool, but are at the same time able to actually use the real tool with less or no errors (De Renzi, Faglioni, & Sorgato, 1982; Goldenberg & Hagmann, 1998; Goldenberg, Hentze, & Hermsdorfer, 2004; Graham, Zeman, Young, Patterson, & Hodges, 1999; Laimgruber, Goldenberg, & Hermsdörfer, 2005; Lausberg, Cruz, Kita, Zaidel, & Ptito, 2003; Rapcsak, Ochipa, Anderson, Poizner, & 1995; Wada et al., 1999). This discrepancy is commonly explained by differences in afferent input (e.g. Binkofski & Buxbaum, 2013; Haaland, Harrington, & Knight, 1999; Jax, Buxbaum, & Moll, 2006; Jax, Rosa-Leyra, & Buxbaum, 2014; Liepmann, 1912; Wada et al., 1999). Holding an actual tool offers both visual and tactile feedback that can assist to guide the action. In contrast, these inputs are not available when pantomiming the same action.

Several studies underlined the role of visual feedback for apractic errors. When performing simple aiming movements, apractic patients achieved similar spatial and temporal precision compared to healthy controls when full visual feedback was available (Haaland et al., 1999). Withdrawal of visual feedback resulted in spatial errors that were larger in apractic compared to non-apractic left-brain damaged patients. Moreover, apractic patients were found to be significantly more affected in imitation tasks if visual feedback was completely removed immediately after presentation of a video-taped action to be imitated (Jax et al., 2006). Further, Jax et al. (2014) successfully predicted severity of apraxia in pantomime from performance in a test for intrinsic coordinate control (i.e. coordinate control relative to the own body) in meaningless imitation in a blindfolded condition, but not in a condition with visual feedback.

These and other findings (Buxbaum et al., 2005; Dawson, Buxbaum, & Duff, 2010) led to the hypothesis that apractic patients pathologically over-rely on visual feedback to compensate deficits in motor planning or execution (Binkofski & Buxbaum, 2013; Haaland et al., 1999; Jax et al., 2006, 2014). Alternatively, others hypothesized that defective pantomime does not rely on the same cognitive motor programs as real action (Goldenberg, 2014; Laimgruber et al., 2005). Improved performance of real versus pantomimed tool use in apraxia thus would arise from a fundamental distinction of processes underlying both skills.

To decide between the two hypotheses it may help to clarify further the impact of visual feedback on apraxia of pantomime. Hitherto, previous studies only varied complete presence versus complete absence of visual feedback for the whole movement. However, object-related movements consist of conceptually and temporally different components, such as a transportation and a manipulation phase (Jeannerod, 1981). It is unclear, for which movement component visual feedback might play a role in apraxia. The aim of the present study thus was to systematically remove visual input in different phases of an action. If over-reliance on visual feedback for online control is the cause for apractic errors (Binkofski & Buxbaum, 2013; Haaland et al., 1999; Jax et al., 2006, 2014), variation of visual feedback should specifically affect apractic patients, at least in critical phases of the movement process. Further, patients' apractic errors in real tool use should converge towards errors in pantomime if visual feedback is removed in such phases of the movement. In order to manipulate visual feedback systematically during the movement we implemented an online motion capturing interface to identify specific time points of the movement, at which shutter glasses could be closed in real-time.

2. Methods

2.1. *Subjects and neuropsychological assessment*

Neurological patients at the University Clinic Tübingen were systematically screened for deficits in pantomime of object use. Apraxia in pantomime was tested with a 20-item test (Goldenberg et al., 2003, Goldenberg, Hermsdörfer, Glindemann, Rorden, & Karnath, 2007) in which patients had to pantomime the use of everyday objects as if they actually held the object in their left (non-paretic) hand. The task was instructed both verbally and by showing pictures of the objects. The testing procedure was recorded on video and rated offline by consensus of two experienced experimenters. For each item, one point could be scored for the correct grip position and one to three points for further aspects as for example amplitude of movement, trajectory, or hand position in relation to the own body. Maximal score was 55 points; the cutoff for apraxia was <45 (Goldenberg et al., 2007). Moreover, for a demographic and clinical overview, patients were tested for apractic deficits in imitation of meaningless hand and finger gestures (Goldenberg, 1996) and were screened for aphasia (Weniger, 2006).

Fourteen neurological patients showing deficits in pantomime of tool use were recruited; four dropped out later. In one patient, online control via VICON-MATLAB interface was not working. The other three patients were not able to perform the experimental task due to cognitive or general impairment; one fell asleep during testing. The remaining ten patients (mean age = 65.9 years, SD = 7.6; see Table 1) were all below the cutoff for apraxia in pantomime of tool use (mean = 37.2 points, SD = 6.9). Seven patients suffered from neurodegenerative diseases; three from left hemisphere stroke (Fig. 1). All three stroke patients also suffered from aphasia, while aphasic disturbances in the neurodegenerative patients were either minimal or not present at all. However, in all ten patients, comprehension was sufficient to follow all instructions. All patients were right-handed. No patient had motor deficits of the upper extremities according to clinical