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Response interference between functional and structural object-related actions is increased in patients with ideomotor apraxia

Steven A. Jax* and Laurel J. Buxbaum

Moss Rehabilitation Research Institute, Elkins Park, Pennsylvania, USA

Abstract

We report data from two left hemisphere stroke patients with moderate-to-severe ideomotor apraxia who exhibited deficits in positioning their hands to use ‘conflict’ objects (objects grasped and used with different hand postures) relative to controls and patients with mild apraxia. These novel data support the claim that actions to common objects are subject to interference between multiple responses, and suggest that errors in apraxia may be attributed to deficient resolution of competition between appropriate and inappropriate actions.

Ideomotor apraxia (IMA) is a disorder of complex skilled action not attributable to elemental sensory or motor impairments. An important observation not addressed by most theoretical models of IMA (e.g., Gonzalez Rothi, Ochipa, & Heilman, 1997) is that many patients have particular difficulties with the hand posture component of skilled use actions involving objects, but exhibit relatively preserved ability to perform prehensile (grasping) actions based upon object structure. To account for this finding, the Two Action Systems (2AS) model suggests that there are important functional and neuroanatomic distinctions between the systems underlying skilled use and grasping (Buxbaum & Kalénine, 2010).

Recently, Jax and Buxbaum (2010) tested the hypothesis that response conflict would be observed between actions mediated by the grasp and use systems by examining (in healthy participants) the degree to which responses would be slowed if objects specify competing hand postures for use and grasp. This study showed that planning use hand postures is significantly slower with familiar objects such as a calculator in which grasp and use postures conflict (grasp = clench, use = poke) than in objects such as a drinking glass without conflict (both = clench). In other words, in ‘conflict’ objects, grasp responses interfere with use responses. We used this same method to test the prediction that IMA patients, who have deficits in use posture representations despite relatively normal grasping behaviours, would exhibit abnormal interference when demonstrating hand postures for using conflict objects.

Methods

Eight consecutively recruited chronic left hemisphere stroke patients and 10 neurologically intact controls completed the study. Patients and controls did not differ in age ($p = .91$) or education ($p = .66$).

The design was nearly identical to Jax and Buxbaum (2010). During the two primary tasks, seated participants interacted with 20 3D everyday objects (Table 1). In the grasp task, they were instructed to reach for and ‘position your hand on the object as you would to hand it to another person’. In the use task, instructions were to reach for and ‘position your hand on the object as you would to use it’. Ten practice trials (with objects not included in later trials) were provided to ensure participants understood the instructions and were performing correctly.

Participants completed two sessions, separated by at least 3 weeks, each including one set of four use blocks and one set of four grasp blocks (task order was randomized across sessions and participants). Within blocks, participants interacted with conflict objects on 10 trials, non-conflict objects on 10 trials, and a red cylinder on two no-go trials. Each trial began with the participant’s left hand resting on a start button. LCD goggles worn by the participant were occluded to prevent vision of the experimenter placing the object in front of the participant’s midline. After a warning tone, the goggles cleared, allowing the participant to see the object and make a movement to grasp or use the object, depending on the block’s instructions, or withhold a response for the no-go object.

We also assessed patients’ language comprehension (Western Aphasia Battery comprehension subtest) and praxis. Apraxia was diagnosed in the left arm using a combined score on 10 trials of pantomime tool use to the sight of objects and 10 trials of imitation of meaningless postures (derived from meaningful postures by changing parameters of hand posture, arm posture, amplitude, or timing; Buxbaum, Kyle, & Menon, 2005). We selected this combined measure to identify deficits in gesture representations (pantomime) as well as deficits in spatial coding (meaningless imitation), both of which can be disrupted in IMA (Buxbaum, 2001; Jax, Buxbaum, & Moll, 2006). We also administered 10 trials of imitation of transitive (object-related) gestures (e.g., hammering). Integrity of conceptual action knowledge was assessed with a test of action recognition in which participants heard and saw an object-use action verb (e.g., ‘writing’) and selected from two video clips the correct clip while rejecting a foil differing in hand configuration (Buxbaum *et al.*, 2005). Each participant completed eight action recognition trials, and there were no time constraints for responding.

Results

The dependent measure was hand posture accuracy, as scored relative to typical hand postures produced by neurologically intact controls in pilot testing. Two independent raters produced highly reliable scores (93.75%). Given the potential for significant patient variability in this small sample, we first examined patients’ scores to determine whether they fell outside of the control range in the use task. Only two patients met this criterion (P1 and

P2). Inferential statistics comparing P1 and P2 to unimpaired patients and controls were done using a BayesianMonte Carlo method (SingleBayes method; Crawford & Garthwaite, 2007). Individual participant data, including demographic data, appear in Table 2.

As shown in Figure 1, P1 was impaired in using both conflict (75%) and non-conflict (91.25%) objects, with accuracy significantly lower for conflict objects ($\chi^2 = 9.00$, $p < .001$). Use errors with conflict objects were predominantly responses that would have been appropriate for grasping (70% of errors).

P2's use of conflict objects was even more markedly impaired, with significantly lower accuracy using conflict objects (21.25%) than non-conflict objects (86.25%; $\chi^2 = 67.98$, $p < .001$). Like P1, use errors with conflict objects were also predominantly grasp-appropriate responses (95% of errors). Although less striking than the deficit in use, P2's grasping of non-conflict objects was also deficient (92.5%).

We next assessed whether differences in performance on other behavioural tasks might underlie the impaired performance of P1 and P2. P1 and P2 had Western Aphasia Battery comprehension scores equivalent to the unimpaired patients ($p = .34$ and $p = .44$, respectively). Apraxia scores (average of pantomime and meaningless imitation) for P1 and P2 were on the lower end of the unimpaired group's distribution; however, this difference was only significant for P2 ($p = .03$; $p = .17$ for P1). When the two component tests of the apraxia score were analysed separately, P2's more severe apraxia (relative to the unimpaired patients) was primarily evident in her poor pantomime to sight of objects ($p = .001$). In contrast, P1 did not significantly differ from the unimpaired patients on pantomime, and neither P1 nor P2 differed from that group on meaningless imitation ($p = .12$ for these three comparisons). Similarly, P1 and P2 were not significantly different from the unimpaired patients on meaningful transitive imitation ($p = .36$ and $p = .39$, respectively). Only on the recognition test of transitive actions were both P1 and P2 significantly less accurate than the unimpaired patients ($p = .03$ and $.002$, respectively).

Discussion

Consistent with the claim that actions to common objects are influenced by competition between multiple responses, two of the eight left hemisphere stroke patients we tested were significantly impaired in demonstrating hand postures for using objects that are grasped and used with different hand postures. Although deficits in skilled use are a hallmark of IMA (Goldenberg & Hagmann, 1998), this study is the first to our knowledge to report that these use errors are particularly strong in patients with moderate-to-severe IMA when a competing inappropriate response is possible. This interference was catastrophic in P2, whose accuracy was 65% lower for demonstrating the use of conflict objects relative to non-conflict objects. This novel observation suggests that errors in IMA, especially moderate-to-severe IMA, may be influenced by deficient resolution of competition between appropriate and inappropriate actions.

The experimental task we used bears some similarities to both pantomime to sight of objects as well as to actual tool use in that participants had to position their hands on the object 'as

if” using or picking it up. Nevertheless, the ‘use’ version of our task appears to elicit deficits of a severity that are not observed on the more traditional praxis tests. This suggests that tests that include a condition with conflict objects may be particularly sensitive to use knowledge deficits.

In our sample, deficits in the use task could not be ascribed simply to larger lesions or greater comprehension deficits in P1 and P2. Instead, specific deficits in conceptual action knowledge reliably differentiated P1 and P2 from the unimpaired patients. Like the experimental task, the action knowledge task assesses the linkage between objects and action use representations, but without the confound of a motor production requirement. This suggests that patients with deficient use action knowledge may be particularly susceptible to interference-based errors.

Critically, these results require replication in a larger sample of patients, which could also clarify several unresolved questions. The first question is whether the observed relationship between response interference and action knowledge deficits will be replicable. Second, it will be important to provide additional evidence that this relationship is specific, and not reflective of other cognitive and/or motor processing deficits.

In conclusion, this initial study extends the results of Jax and Buxbaum (2010) which showed increased competition and slowing when healthy participants used conflict objects. It suggests a potential role for response competition in action errors in IMA, just as response competition is thought to play a role in the production of errors in aphasia (e.g., Schnur, Schwartz, Brecher, & Hodgson, 2005). Consideration of this competition may be useful in future studies of apraxia. Our results suggest that when demonstrating the use of non-conflict objects, apraxics may use their relatively intact grasp systems to mask the true extent of their deficits. When tested on the use of conflict objects, for which hand postures for using and for moving objects are distinct, the true extent of a patient’s deficits can be observed. Thus, testing with conflict objects may be especially sensitive in diagnosing apraxia. Beyond diagnosis, additional investigations of competition effects in the action domain may have implications for the remediation of apraxia, just as reduction of competition (e.g., through focused cueing procedures; Edmonds & Babb, 2011) may facilitate language production.

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Figure 1.

Individual accuracy data for P1 (red line) and P2 (blue line), as well as averaged data from the remaining six unimpaired patients (dashed line) and all controls (solid black line). Conditions in which either P1 or P2 were significantly ($p < .05$) less accurate than both the control group and unimpaired patient group are indicated with asterisks.

Table 1

Stimuli

Conflict objects			Non-conflict objects	
Object	Grasp posture	Use posture	Object	Grasp/use posture
Calculator	Clench	Poke	Floss	Clench
Blender	Clench	Poke	Ice cream scoop	Clench
Shaving cream	Clench	Poke	Salt shaker	Clench
Light switch	Clench	Poke	Baseball	Clench
Toaster	Clench	Poke	Dish detergent	Clench
Pump soap	Clench	Palm	Flashlight	Clench
Three-hole punch	Clench	Palm	Sponge	Clench
Stapler	Clench	Palm	Glue	Clench
Padlock	Clench	Pinch	Cup	Clench
Timer	Clench	Pinch	Screwdriver	Clench

Table 2

Participant information

	Age	Education	Lesion volume (mm ³)	WAB compr.	Apraxia score	Pant. to sight	Mnls. init.	Trans. init.	Trans. recogn. (hand)	Accuracy use conflict	Accuracy use non-conflict	Accuracy grasp conflict	Accuracy grasp non-conflict
P1	54	13	103,943	9.8	75	82.5	67.5	76.7	50	75	91.3	91.3	92.5
P2	50	12	59,961	9.6	61.3	50	72.5	77.6	25	21.3	86.3	91.3	100
P3	54	12	51,860	9.6	85	90	80.0	85.9	75	100	100	98.8	100
P4	56	12	52,518	10	89	90.6	87.5	90.0	75	93.8	100	97.5	100
P5	61	18	266,061	8.8	75	77.5	72.5	82.5	75	98.8	100	98.8	100
P6	51	16	150,768	10	77.5	87.5	67.5	66.1	87.5	88.8	92.5	94.9	96.3
P7	79	12	16,038	9.9	77.5	85	70.0	75.0	62.5	88.8	100	100	100
P8	54	11	76,184	7.9	82.5	90	75.0	81.7	62.5	92.5	98.8	92.5	100
U.P. average	59.2	13.5	102,238.2	9.4	81.1	86.7	75.4	80.2	72.9	93.8	98.5	97.1	99.4
U.P. S.D.	10.3	2.8	91,991.7	0.9	5.3	5.0	7.3	8.5	9.4	4.8	3.0	2.8	1.5
Control average	57.2	13.8								92.4	99.9	99.1	99.8
Control S.D.	5.4	4.3								5.3	0.4	1.9	0.8

Note. U.P., unimpaired patients (P3–P8); compr., comprehension; pant., pantomime; trans., transitive; init., imitation; mnls, meaningless; recogn., recognition. Bolded scores are more than two standard deviations below the mean score of healthy controls reported previously (Buxbaum, Kyle, & Menon, 2005; Buxbaum, Kyle, Grossman, & Coslett, 2007).