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**MECHANICAL KNOWLEDGE DOES MATTER TO TOOL USE EVEN WHEN  
ASSESSED WITH A NON-PRODUCTION TASK: EVIDENCE FROM LEFT BRAIN-  
DAMAGED PATIENTS**

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**Abstract**

In the literature on apraxia of tool use, it is now accepted that using familiar tools requires semantic and mechanical knowledge. However, mechanical knowledge is nearly always assessed with production tasks, so one may assume that mechanical knowledge and familiar tool use are associated only because of their common motor mechanisms. This notion may be challenged by demonstrating that familiar tool use depends on an alternative tool selection task assessing mechanical knowledge, where alternative uses of tools are assumed according to their physical properties but where actual use of tools is not needed. We tested 21 left brain-damaged (LBD) patients and 21 matched controls with familiar tool use tasks (pantomime and single tool use), semantic tasks and an alternative tool selection task. The alternative tool selection task accounted for a large amount of variance in the single tool use task and was the best predictor among all the semantic tasks. Concerning the pantomime of tool use task, group and individual results suggested that the integrity of the semantic system and preserved mechanical knowledge are neither necessary nor sufficient to produce pantomimes. These results corroborate the idea that mechanical knowledge is essential when we use tools, even when tasks assessing mechanical knowledge do not require the production of any motor action. Our results also confirm the value of pantomime of tool use, which can be considered as a complex activity involving several cognitive abilities (e.g., communicative skills) rather than the activation of gesture engrams.

*Keywords: mechanical knowledge; alternative tool selection task; tool use; left brain-damaged patients; semantic knowledge*

## Introduction

In the literature on apraxia of tool use, it is widely accepted that using familiar tools requires semantic knowledge about tool function (i.e. what an object is for; Buxbaum, Schwartz, & Carew, 1997; Cubelli, Marchetti, Boscolo, & Della Sala, 2000) and manipulation (how an object is used; Buxbaum, 2001; Buxbaum, Kyle, Grossman, & Coslett, 2007). However, brain-damaged patients with a deficit in the stored semantic knowledge of tool use can exhibit spared abilities to use tools (Negri, Lunardelli, Reverberi, Gigli, & Rumiati, 2007; Sirigu, Duhamel, & Poncet, 1992). Therefore, the ability to use tools may be sustained by another form of knowledge. The concept of mechanical knowledge refers to the capacity to infer possible uses of both familiar and novel tools from analysis of their structural properties (Buxbaum, 2001; Daprati & Sirigu, 2006; Goldenberg & Hagmann, 1998; Hartmann, Goldenberg, Daumüller, & Hermsdörfer, 2005; Heilman, Maher, Greenwald, & Rothi, 1997; Hodges, Bozeat, Lambon Ralph, Patterson, & Spatt, 2000; Osiurak, 2014; Osiurak et al., 2009; Osiurak, Jarry, & Le Gall, 2010, 2011; Osiurak & Badets, 2016; Osiurak & Lesourd, 2014). An association between impaired tool use and decreased mechanical knowledge has been observed in left brain-damaged (LBD) patients and in patients with neurodegenerative disorders (Baumard et al., 2016; Goldenberg & Hagmann, 1998; Jarry et al., 2013; Lesourd, Baumard, Jarry, Etcharry-Bouyx, et al., 2016).

Mechanical knowledge (e.g., knowing how to cut, leverage, etc) is abstract and based on the understanding of opposition existing between properties<sup>1</sup>. For instance, understanding the cutting action is equal to understanding the relative opposition between one thing possessing the properties ABRASIVENESS+, HARDNESS+, and WIDTH- and another

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<sup>1</sup> Mechanical knowledge is also called inference from structure to function (Goldenberg & Hagmann, 1998), mechanical reasoning (Hegarty, 2004) or intuitive physics (McCloskey, 1983). Although there are subtle differences between each of these conceptions, this debate is beyond the scope of the present article. Herein we refer only to mechanical knowledge (Osiurak, Jarry, & Le Gall, 2010).

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possessing the properties ABRASIVENESS-, HARDNESS-, and WIDTH+ (e.g., Osiurak, 2014). Moreover, it has been found in LBD patients that mechanical knowledge is distinct from semantic knowledge, as distinct cortical areas support mechanical knowledge and semantic knowledge about tool use, namely the left inferior parietal lobe and the left temporal lobe, respectively (Goldenberg & Spatt, 2009). Finally, it has been recently shown in normal aging that semantic and mechanical tasks saturate two independent factors, suggesting that mechanical and semantic tasks are subsumed by two distinct cognitive processes (Lesourd, Baumard, Jarry, Le Gall, & Osiurak, 2017).

Mechanical knowledge is commonly investigated by asking subjects to solve mechanical problems (Bartolo, Daumüller, Della Sala, & Goldenberg, 2007; Baumard et al., 2016; Goldenberg & Hagmann, 1998; Jarry et al., 2013; Ochipa, Rothi, & Heilman, 1992). For example, in the choice condition of the Mechanical Problem-Solving Task (e.g., Lesourd, Baumard, Jarry, Le Gall, et al., 2017), participants are asked to choose the most appropriate of several tools to extract a target that is stuck inside a box. Another way to explore mechanical knowledge is the unusual use of tools test (Osiurak et al., 2009), in which participants are asked to find an unusual purpose for the tool provided (e.g., screwing in a screw with a knife). Finally, in the alternative tool selection task (e.g., Le Gall, Morineau, & Etcharry-Bouyx, 2000), subjects are asked to select from a list of items a tool (e.g., fork) that shares critical physical features with the familiar tool (e.g., comb) used to perform an intended action (combing hair) but which is not available. Except for the latter task, the achievement of a purposive action is nearly always required in tasks assessing mechanical knowledge.

Thus, a possible interpretation of the strong association existing between tool use and mechanical knowledge tasks is that both tasks require the production of a motor action. Thus, familiar tool use would not be subsumed by mechanical skills *per se* but would simply be associated with mechanical problem-solving tasks because of their common motor nature. In

line with this idea, Osiurak et al. (2009), using a multidimensional scaling of correlations between experimental tests in LBD patients, found that familiar tool use and unusual use of tools were similar whereas alternative tool selection was very different from the other two types of tool use tasks.

One way to challenge the notion that mechanical knowledge and tool use are associated only because they both require the production of a motor action is to demonstrate that familiar tool use depends on an alternative tool selection task. Indeed, in this task, subjects are asked to guess alternative uses of tools based on their physical properties, but the actual use of tools is not needed. If familiar tool use depends on mechanical knowledge, an alternative tool selection task would be the best predictor to explain the amount of variance between familiar tool use tasks. To assess familiar tool use, we used a single tool use task and a pantomime of tool use task (e.g., Jarry et al., 2013). However, the alternative tool selection task could be claimed not to be purely mechanical as semantic features are made available through the tools presented in it. To circumvent this objection, we used several semantic tasks (i.e., function, associative, manipulation and identity matching) in an attempt to establish that the alternative tool selection task, although not a pure mechanical task (e.g., Mechanical Problem-Solving task; Lesourd, Baumard, Jarry, Etcharry-Bouyx, et al., 2016), is the best predictor among all the semantic tasks.

## **Methods**

### ***Participants***

Twenty-one LBD right-handed patients (mean age = 65.2 SD = 13.9; 12 females) and 21 healthy controls (mean age = 62.0 SD = 7.0, 9 females) matched for age and educational level participated in the study. Clinical CT or MRI scans were available for all patients but the quality of the patients' brain images, which were collected primarily for clinical purposes, did

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not allow us to use modern neuroimaging analyses (e.g., VLSM; Kimberg, Coslett, & Schwartz, 2007). All controls were right-handed with normal or correct-to-normal vision, with no history of neurological or psychiatric disease and normal Mini Mental State Examination scores (range = 26 - 30; mean = 29.4; SD =1.4; Measso et al., 1993; Folstein, Folstein, & McHugh, 1975). Written informed consent was obtained from all subjects and the study was conducted in accordance with the Declaration of Helsinki.

### ***Experimental tasks***

All experimental tasks comprised 15 items and always began with two examples for which feedback on the correctness was given. The list of items used in each experimental task is provided in supplementary material. Cut-off scores were determined as the worst scores achieved by the controls minus two more points for all experimental tasks (Bartolo, Cubelli, Della Sala, & Drei, 2003).

#### *Pantomime of tool use (PTU)*

Participants were presented with one tool at a time (comb, hammer, pen, key, cigarette, glasses, ring, needle, racket, salt-shaker, screwdriver, watering can, phone, iron and glass). They were instructed to show how they would use the tools without holding them in their hand. The performance was rated on a 2-point scale, one point was attributed if the pantomime was correctly performed and clearly recognizable (maximum = 15) and no point was given if the action contained any errors (hand/arm posture, amplitude, timing or content errors; e.g., Buxbaum, Kyle, & Menon, 2005). A score of 0 was attributed if the action contained one or several of the following errors: (1) hand/arm movement flagrantly incorrect or hand/arm moved in a flagrantly incorrect plane or direction (i.e., hand/arm posture error); (2) action flagrantly too large or too small (i.e., amplitude error); (3) movement too quick or too slow or performed with too many or too few iterations (i.e., Timing error); (4) action is a

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recognizable semantic substitution (i.e., content error). As we could not record the patients' performance, we cannot provide a measure of inter-rater reliability (e.g., Kappa's Cohen). However, all patients were evaluated by an expert in the field of limb apraxia (A.B.) which was one of the authors. All participants performed this task with the left hand.

#### *Single tool use (STU)*

The same 15 tools used in the pantomime of tool use task were proposed in this task. One tool was placed at a time on the table and participants were asked to grasp the tool and to demonstrate its typical use. The performance was rated on a 2-point scale, one point was given if the expected action was directly undertaken (maximum = 15) and no point was given if the action contained any errors, which were rated as in the PTU task. All participants performed this task with the left hand.

#### *Alternative tool selection*

In the alternative tool selection task, participants were shown an **action verb/phrase** (e.g., hammering a nail into a wall) and three pictures of objects (e.g., saw, shoe and brush). The participants were asked to select among the three objects the one that could be used to perform the intended action. As the tool usually used to perform the action was always absent (e.g., hammer), the participants were asked to select which of the tools had the physical features required to perform the action (i.e., the heel of the shoe could be used to knock the nail into the wall). One point was attributed for each correct answer (*maximum* = 15).

#### *Manipulation matching*

In the manipulation matching task, participants were shown three objects simultaneously (e.g., slingshot, sword, bow) and were asked to choose the two that required the same manner of manipulation and could be mimed in the same way. For instance, when a slingshot, a sword



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and a bow were presented, participants had to select the slingshot and the bow because they are both manipulated in the same way. For each object, participants were invited to think about the position of their hand/fingers and the movement while using the objects. One point was attributed for each correct answer (*maximum* = 15).

#### *Function matching*

In the function matching task, participants were asked to choose among three objects (e.g., candle, cigarette and lamp) the two that shared the same function and could be used for the same purpose. For instance, when a candle, a cigarette and a lamp were presented, participants had to select the candle and the lamp because they are both used for the same function, i.e. to illuminate. One point was attributed for each correct answer (*maximum* = 15).

#### *Associative matching*

In the associative matching task, participants were presented with a target object (e.g., a hammer) followed by two objects (e.g., a screw and a nail) and were asked to choose the one that was more likely to be used with the target object. In this example, participants had to select the nail because it is typically used with the hammer. One point was attributed for each correct answer (*maximum* = 15).

#### *Identity matching*

In the identity matching task, participants were presented with three line-drawing pictures of objects (e.g., two pictures of distinct hats and a picture of a suitcase). Two of the three objects were two exemplars of the same category, although with different visual characteristics. Participants were instructed to select the two exemplars belonging to the same category. One point was attributed for each correct answer (*maximum* = 15).

### ***Statistical analysis***

Correlations between demographical and clinical data (i.e., age, educational level) and experimental tasks were performed in both groups. Comparisons between LBD patients and controls were made using Mann-Whitney tests. Comparisons between tool use tasks (STU and PTU) for each group independently were performed using Wilcoxon tests. Matrix correlations were computed between all experimental tasks in LBD patients and controls. To further study the correlational structure of test results in LBD patients, multidimensional scaling of correlations between tests was also computed in LBD patients. Finally, to find the best predictors of PTU and STU scores in LBD patients, we used multiple stepwise regression analyses. Thus, STU and PTU scores were used as criterion and Manipulation, Function, Associative and Identity matching and Alternative selection scores were used as predictors.

All statistical analyses were performed with R statistical software (R Development Core Team, 2008).

## **Results**

### ***Effects of demographical and clinical data in control group and LBD patients***

Demographical and clinical data are shown in **Table 1**. Controls and LBD patients were matched according to gender, age and educational level. No significant associations were found between demographical (i.e., age, education level) and experimental tasks in both groups. Moreover, no association was found between lesion onset and experimental scores in LBD patients. As these demographical and clinical variables were not associated with experimental scores, we did not include them in the subsequent regression analyses.

< Insert **Table 1** about here >

### ***Comparisons between groups and tool use tasks***

**Table 2** displays the results of experimental tasks for the controls and the LBD patients. LBD patients scored significantly lower than controls on all experimental tasks (all  $ps < .001$ ; **Fig.1**). Moreover, controls and LBD patients significantly improved their performance between PTU and STU tasks ( $p = .012$  and  $p < .001$ , respectively).

< Insert **Table 2** and **Figure 1** about here >

### ***Correlation between experimental tasks***

Correlation matrices between tasks are shown in **Table 3** for controls and LBD patients. For LBD patients, we found significant correlations between tool use tasks (i.e., STU and PTU) and all the other tasks (all  $r > .45$ , all  $ps < .05$ ). Moreover, Alternative tool selection scores were significantly associated with all the tasks assessing semantic knowledge (i.e., Function, Associative and Identity matching, all  $r > .73$ , all  $ps < .001$ ). In controls, no association was found between PTU task and the other tasks. Moreover, the Alternative tool selection scores were significantly correlated with Manipulation scores ( $r = .51$ ,  $p = .02$ ).

< Insert **Table 3** about here >

To further explore the structural properties of the correlation matrix in LBD patients, it was subjected to multidimensional scaling which yields a graphical representation of the correlational structure (Young, 1987). Higher correlations are represented by smaller distances between the respective data points. The distances correspond to the rank order of the correlations but not necessarily to their absolute values. For LBD patients, multidimensional scaling analysis achieved a fair two-dimensional representation (Kruskal stress = .14,  $r^2 = .92$ ; **Fig.2**). There was a separation between STU task and all the other experimental tasks which may be explained by the presence/absence of tool. Indeed, STU was the only task requiring

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the actual manipulation of a tool compared to the other tasks. We found that Alternative tool selection and Associative matching were strongly associated and occupied an intermediate position almost equidistant from the other tasks. Manipulation matching and PTU were also strongly associated. Finally, Function matching and more particularly Identity matching were isolated from the other tasks.

< Insert **Figure 2** about here >

### ***Multiple stepwise regression analyses in LBD patients***

To investigate which of the correlated variables explained a significant amount of variance in STU and PTU tasks, we carried out multiple stepwise regression analyses. Results of the multiple regressions are shown in **Table 4**.

< Insert **Table 4** about here >

When STU scores were predicted, Alternative tool selection ( $\beta = .85, p < .01$ ), Associative ( $\beta = .65, p < .01$ ) and Function matching ( $\beta = -.72, p < .05$ ) were found to be significant predictors and the model was able to account for 72% of the variance,  $F(3,17) = 14.75, p < .001, R^2 = .72, R^2_{adj.} = .67$ . When PTU scores were predicted, Alternative tool selection ( $\beta = .46, p < .05$ ) and Manipulation ( $\beta = .46, p < .05$ ) were found to be significant predictors and the model was able to account for 70% of the variance,  $F(2,18) = 20.95, p < .001, R^2 = .70, R^2_{adj.} = .67$ .

### ***Multiple single case approach***

Patients' results were also analyzed by considering each individual performance. To avoid false positive scores, we established conservative cut-offs as the scores of the worst control minus two points. This method has already been used (Bartolo et al., 2003). Among the 21 patients, 7 had scores above the cut-off in all the tasks administered. In the STU task, only

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three patients (P3, P5 and P8) had pathological performances<sup>2</sup>. All of them showed deficits in all the tasks administered, except P3 who had normal performance in the Associative matching task. In the PTU task, apart from the 3 patients above, the other 7 patients (P9, P10, P12 P15, P16, P18 and P21) had performances below the cut-off coupled with spared ability to use tools. P15 had difficulties in all the tasks. P9 and P18 had difficulties in all the tasks except the Alternative tool selection task. P10 failed all the tasks except the Associative matching task. P16 failed only the Function matching task, yet his scores on the Alternative tool selection and Manipulation matching tasks were at the cut-off. P21 failed only the Manipulation matching task, whereas P12 passed all the tasks. The other 4 patients (P6, P7, P17 and P19) showed preserved abilities in the single tool use task and could produce pantomimes above the cut-off. However, P6, P7 and P17 had selective deficits in the Manipulation matching task, whereas P19 had difficulties in all the semantic and the Alternative tool selection tasks.

## Discussion

In recent years, mechanical knowledge has been strongly associated with the ability to use tools (Baumard et al., 2016; Baumard, Osiurak, Lesourd, & Le Gall, 2014; Goldenberg & Hagmann, 1998; Jarry et al., 2013; Lesourd, Baumard, Jarry, Le Gall, et al., 2016). However, mechanical knowledge is nearly often assessed with production tasks (e.g., Mechanical Problem-Solving task; Lesourd, Baumard, Jarry, Le Gall, et al., 2017). Therefore, one may assume that mechanical knowledge and tool use are linked as they both require the production

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<sup>2</sup> In the STU task, all controls performed at ceiling level ( $n = 15/15$ ) which means that even the worst control obtained the maximum score. A ceiling effect can virtually minimize the differences between the performance of patients and controls in that these differences might be greater if the task was slightly more difficult (for a discussion see Lesourd et al., 2013). Thus, our single case approach relies only upon three LBD patients with impaired performance according to our conservative cut-offs, but it is likely that more patients would have **been** impaired if the STU task had been more difficult or the cut-off score less strict. However, it is quite difficult to make an STU task more difficult.

of a motor action. The main purpose of the present study was to demonstrate that familiar tool use may be explained by an Alternative tool selection task where the actual use of tools is not needed. Here, we found that the Alternative tool selection task was a significant predictor and accounted for a large amount of variance in the STU and PTU tasks. Moreover, LBD patients were impaired in the Alternative tool selection task compared to controls<sup>3</sup>, as already observed with classical tasks assessing mechanical knowledge (e.g., Sequential Mechanical Problem Solving; Jarry et al., 2013; Osiurak, Jarry, Lesourd, Baumard, & Le Gall, 2013). This result corroborates the idea that mechanical knowledge is of primary importance when we use tools (Osiurak et al., 2010), even if tasks assessing mechanical knowledge do not require the production of any motor action.

As the Alternative tool selection task is not purely mechanical and semantic features are available through the tools presented in it, the second purpose of this work was to demonstrate that the Alternative tool selection task is the best predictor of all the semantic tasks. Our hypothesis seems to be verified by the STU. The Alternative tool selection task was selected in the regression model as the better predictor of two semantic tasks (i.e., Function and Associative matching), suggesting that subjects may reason about the physical properties of tools even in the STU task (Baumard et al., 2014). Interestingly, the Manipulation matching task was not selected in the model to explain the amount of variance in the STU task, suggesting that mechanical and semantic knowledge (Associative and Function) may replace manipulation knowledge when we use familiar tools, as recently proposed by Goldenberg (2013). In line with this hypothesis, multidimensional scaling analysis showed that the Alternative tool selection and the Associative matching tasks were strongly associated and occupy a central position almost equidistant to the other tasks, which was not the case for the

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<sup>3</sup> Our group of LBD patients were impaired in all experimental tasks investigating tool use skills and knowledge supporting tool use, which is similar with previous findings in LBD patients (Jarry et al., 2013).

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Manipulation matching task. These findings question the idea that people directly activate the gesture engram associated with the usual use of tools (see Osiurak et al., 2011 for a discussion). Moreover, individual results examined with a conservative criterion revealed 7 patients (P1, P2, P4, P11, P13, P14 and P20) with spared abilities in all the tasks administered and 3 severe patients (P3, P5 and P8) with deficits in all the tasks (only P3 was at the cut-off in the Associative task). Intriguingly, the profiles of these patients show that tool use is always impaired in association with deficits in all the semantic and mechanical tasks. This suggests that a combination of deficits in the semantic system and in mechanical problem-solving skills favors the emergence of this defective behavior, as already reported (Goldenberg & Hagmann, 1998). Interestingly, the performance of P15 in the tool use task was at the cut-off regardless of deficits in all the other tasks. In particular, he was particularly deficient in the Manipulation and Function matching tasks (4/15 in both cases), whereas his performance on the Alternative tool selection and the Associative matching tasks were close to the cut-offs, in line with our findings that skills on these tasks play an important role in the tool use test. P10 had similar profile with a normal score on the Associative matching task. Finally, mechanical and semantic knowledge (Associative and Function) are good predictors of STU, as already observed in other familiar tool use tasks (i.e., real tool use tasks<sup>4</sup>; Lesourd, Baumard, Jarry, Le Gall, et al., 2017), even if mechanical knowledge seems to be more critical (Osiurak et al., 2009).

Concerning the PTU task, the group results are less straightforward than for the STU task. Indeed, the Alternative tool selection and Manipulation matching tasks were both selected as significant predictors and explained the same amount of variation as obtained in the PTU task. At first glance, this seems quite logical given that (1) the activation of manipulation

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<sup>4</sup> In real tool use tasks (Baumard et al., 2016; see also Jarry et al., 2013), participants are asked to use a tool with an object (e.g., a hammer and a nail) whereas only the tool is given in our single tool use task.

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knowledge is considered to be a prerequisite to pantomime the use of tools (e.g., Niessen, Fink, & Weiss, 2014); and that (2) it has recently been shown that mechanical knowledge is involved in pantomiming the use of tools (Baumard et al., 2014; Lesourd, Baumard, Jarry, Etcharry-Bouyx, et al., 2017). However, regarding individual results in the pantomime production task, P12 and P19 had intriguing profiles. P12 had preserved semantic and mechanical skills coupled with deficits in the production of pantomimes while P19 had exactly the opposite profile, i.e. spared ability to produce pantomimes and difficulties in all the semantic and mechanical tasks. The results of these two patients point to a double dissociation between a production and a receptive system and suggest that the integrity of the semantic system and preserved mechanical problem-solving skills are neither necessary nor sufficient to produce pantomimes (Negri et al., 2007). This is also confirmed by the profiles of P9, P16, P18 and P21 who showed preserved ability to perform the mechanical task yet failed in the production of pantomimes. With regard to manipulation knowledge, P6, P7 and P17 were able to produce pantomimes, regardless of deficits in Manipulation matching. Thus, PTU is a complex motor activity which is subsumed by several cognitive abilities (i.e., communicative skills; Goldenberg, 2017; for a similar view see also Lesourd et al., 2017).

The performance of both controls and LBD patients were significantly better with STU than with PTU. Brain-damaged patients are known to have a better performance when asked to use tools in hand than by pantomime (De Renzi, Faglioni, & Sograto, 1982; Wada et al., 1999). It has been hypothesized that haptic feedback from the manipulated tool might offer additional cues to facilitate the access to defective sensorimotor (i.e., manipulation) knowledge. However, we found that distinct predictors explained the PTU and STU tasks. Moreover, the Manipulation matching task (i.e., manipulation knowledge) did not explain the STU scores. Taken together, these data may suggest that different forms of knowledge support the STU and PTU tasks and that haptic feedback may not be sufficient to improve performance



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between the tasks. For instance, other studies found that haptic feedback does not systematically improve performance (Goldenberg, Hentze, & Hermsdörfer, 2004; Hermsdörfer, Hentze, & Goldenberg, 2006). When patients were asked to handle a short wooden bar while performing a pantomime task with visual presentation of the tool (i.e., visuo-tactile condition), performance was similar to that in the visual-only condition.

We found a link between tasks assessing mechanical and manipulation knowledge (i.e., Alternative tool selection and Manipulation matching tasks) in both controls and in LBD patients, as already reported in other brain diseases (i.e., Alzheimer's disease and semantic dementia; Lesourd et al., 2017). However, the link between mechanical and manipulation knowledge is still a matter of debate between the gesture engram and technical reasoning theories (for a discussion see Buxbaum, 2017; Osiurak & Badets, 2016, 2017). Buxbaum (2017) proposes the neurocognitive model “Two Action Systems Plus” (2AS+) which includes both mechanical and manipulation knowledge. In 2AS+, mechanical knowledge may be supported by a dorso-dorsal route whereas manipulation knowledge may be supported by a ventro-dorsal route in the parietal lobes. However, this theory seems to be at odds with a recent meta-analysis of neuroimaging studies which reported the specific involvement of area PF in the left supramarginal gyrus for mechanical knowledge (Reynaud, Lesourd, Navarro, & Osiurak, 2016; see also Orban & Caruana, 2014), suggesting that mechanical knowledge may be sustained by a ventro-dorsal route rather than a dorso-dorsal route. To sum up, while neuropsychological evidence provides support for a link between tasks assessing manipulation and mechanical knowledge, further studies are needed to improve our understanding about the function and the neurocognitive bases of mechanical and manipulation knowledge when we use tools.

## **Conclusion**

In this work, we found that an Alternative tool selection task assessing mechanical knowledge and which did not need the production of a motor action was the best predictor of a familiar tool use task (i.e., STU task). This result confirms the major role of mechanical knowledge in tool use (Goldenberg & Hagmann, 1998; Osiurak et al., 2009, 2010) by demonstrating that our abilities to reason about the physical properties of tools and objects may sustain our ability to use familiar tools. We also show that manipulation and mechanical knowledge are both predictors of the PTU task and found a significant correlation between these two tasks. However, the individual results suggest that pantomime production does not depend on any semantic or mechanical knowledge. Given the debate in the literature on tool use about manipulation and mechanical knowledge, further studies are needed to clarify the link between these two forms of knowledge.

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## Figures

**Figure 1.** Representation of raw scores on experimental tasks in Controls and LBD patients. Boxplots display interquartile range (minimum, first quartile, median, third quartile, and maximum). STU: Single Tool Use; PTU: Pantomime of Tool Use; Alter.: Alternative selection; Manip.: Manipulation; Func.: Function; Assoc.: Associative; Ident.: Identity. All comparisons with Controls are significant with \*\*\*  $p < .001$ .

**Figure 2.** Multidimensional scaling of correlations between experimental tasks in LBD patients. Shorter distances between points represent higher correlations between tasks. STU: Single Tool Use; PTU: Pantomime of Tool Use; Alter.: Alternative selection; Manip.: Manipulation; Func.: Function; Assoc.: Associative; Ident.: Identity. Explanations are given in the text.

**Fig.1**

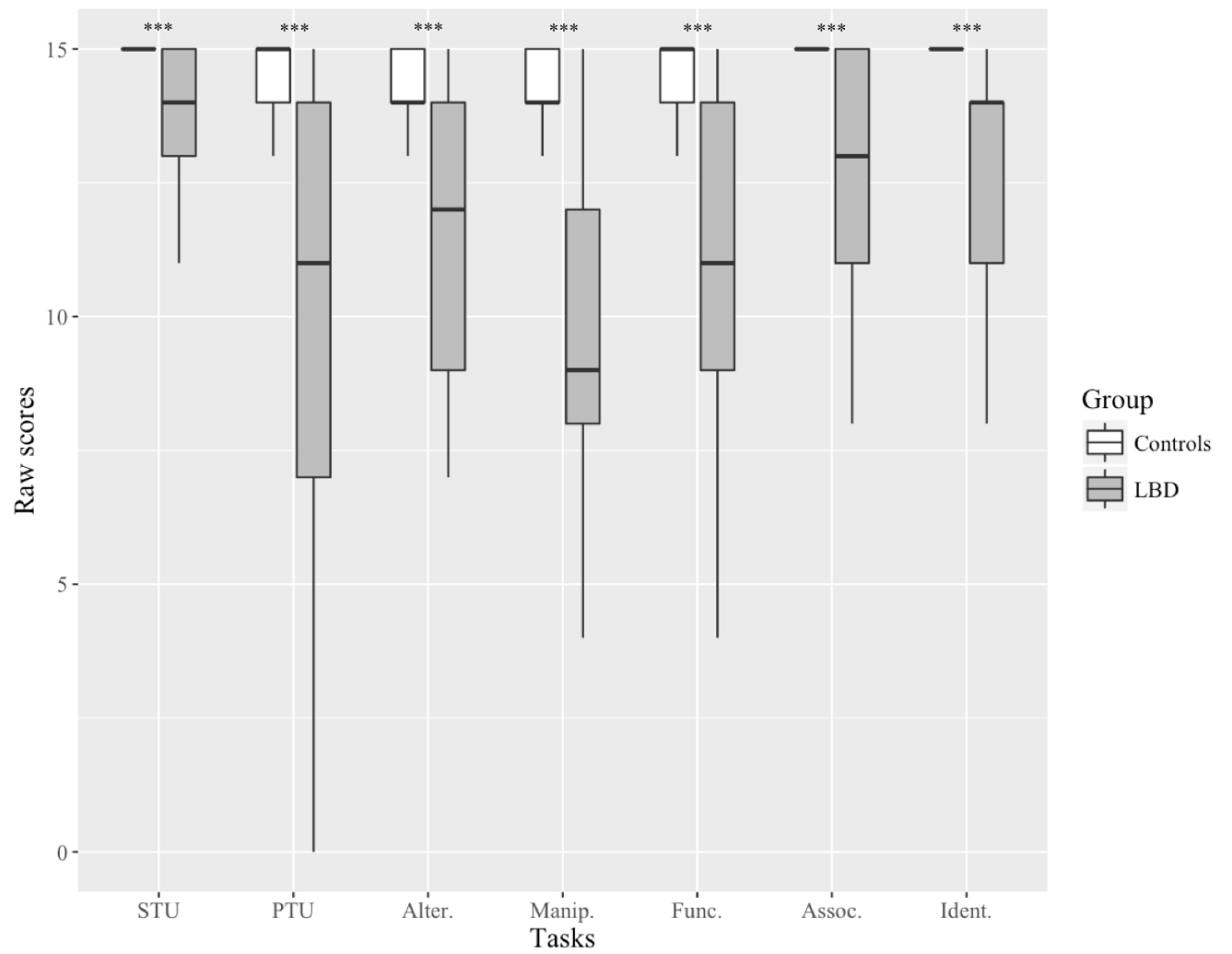
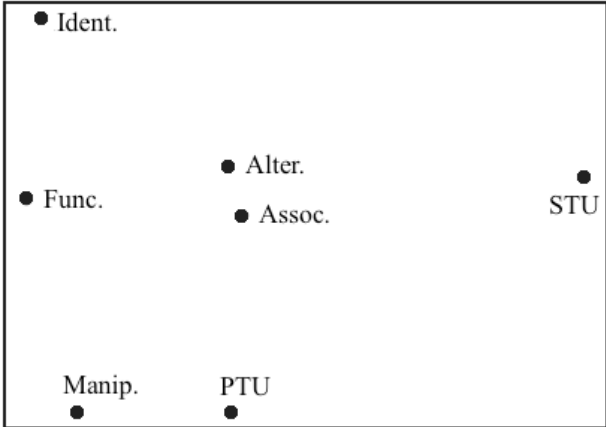


Fig.2



**Table 1.** Demographic and clinical data

	Controls (n = 21)	LBD (n = 21)	LBD vs Controls
Gender (women/men)	12/9	9/12	ns
Age (years)	62.0 (7.0)	65.2 (14.0)	ns
Education (years)	9.0 (3.9)	7.2 (4.1)	ns
Type of lesion (CVA/Lob./Aneu.)	-	17/2/2	-
Time since lesion (months)	-	160.1 (79.6)	-

Between-group comparisons were performed with Mann Whitney *U*-tests, except for "gender" (Chi-2 analysis)

CVA: Cerebral Vasular Accident; Lob.: Lobectomy; Aneu.: Aneurysm

Values in parentheses are standard deviations.

**Table 2.** Results of experimental tasks in controls and LBD patients

	STU	PTU	Alter.	Manip.	Func.	Assoc.	Ident.	Lesion site
Controls								
Mean	15	14.38	14.29	14.29	14.38	14.86	14.81	
Standard deviation	-	.86	.85	.85	.86	.36	.40	
Range	15	13-15	12-15	12-15	12-15	14-15	14-15	
Cut-off <sup>a</sup>	13	11	10	10	10	12	12	
LBD patients								
P1	14	15	11	15	13	15	14	T, F, I
P2	15	15	15	12	14	15	15	F, BG
P3	<b>9</b>	<b>8</b>	<b>8</b>	<b>9</b>	<b>9</b>	12	<b>11</b>	n/a
P4	15	15	15	15	15	15	15	F, T, P, I
P5	<b>5</b>	<b>0</b>	<b>7</b>	<b>4</b>	<b>6</b>	<b>8</b>	<b>11</b>	T, BG
P6	15	14	13	<b>9</b>	11	13	13	F, P
P7	14	11	12	<b>6</b>	10	13	14	T, I
P8	<b>11</b>	<b>6</b>	<b>9</b>	<b>6</b>	<b>8</b>	<b>9</b>	<b>8</b>	n/a
P9	14	<b>8</b>	13	<b>8</b>	<b>9</b>	<b>11</b>	<b>11</b>	F, I, T, P, BG
P10	14	<b>3</b>	<b>9</b>	<b>8</b>	<b>6</b>	14	<b>9</b>	F, T, I
P11	13	14	14	13	14	14	14	F, P
P12	13	<b>7</b>	12	11	14	12	15	T, P, BG
P13	15	13	15	12	13	15	15	BG
P14	15	14	15	13	15	15	15	F, P
P15	13	<b>5</b>	<b>9</b>	<b>4</b>	<b>4</b>	<b>10</b>	<b>11</b>	F, T, I, BG
P16	14	<b>8</b>	10	10	<b>9</b>	12	14	F, I, BG
P17	15	15	13	<b>8</b>	12	14	12	F, I, BG
P18	14	<b>7</b>	12	<b>8</b>	<b>9</b>	<b>11</b>	<b>11</b>	T, BG
P19	13	11	<b>9</b>	<b>9</b>	<b>7</b>	<b>11</b>	<b>8</b>	F, I
P20	14	14	14	12	15	15	14	BG
P21	15	<b>5</b>	12	<b>6</b>	13	15	14	BG
Mean	13.33	9.90	11.76	9.43	10.76	12.81	13.93	
Standard deviation	2.42	4.58	2.53	3.26	3.37	2.18	1.22	

STU: Single Tool Use; PTU: Pantomime of Tool Use; Alter.: Alternative selection; Manip.: Manipulation; Func.: Function; Assoc.: Associative; Ident.: Identity

F: Frontal; T: Temporal; P: Parietal; I: Insulae; BG: Basal Ganglia; n/a: not available

<sup>a</sup> Cut-off scores were determined as the worst score achieved by the controls minus two points (Bartolo et al., 2003)

Values in bold reveal pathological scores for patients relative to controls

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**Table 3.** Correlations between test results (Pearson's product moment) in controls ( $n = 21$ ) and LBD patients ( $n = 21$ )

Tasks	Controls							LBD						
	STU	PTU	Alter.	Manip.	Func.	Assoc.	Ident.	STU	PTU	Alter.	Manip.	Func.	Assoc.	Ident.
STU		-	-	-	-	-	-	.61**	.73***	.45*	.50*	.71***	.43*	
PTU			.05	.12	.13	.35	-.07		.76***	.76***	.73***	.70***	.54*	
Alter.				.51*	.25	-.02	.02			.64**	.84***	.73***	.73***	
Manip.					.12	-.02	-.13				.78***	.71***	.60**	
Func.						.02	.22					.78***	.81***	
Assoc.							-.20						.68***	
Ident.														

\*\*\*  $p < .001$  ; \*\*  $p < .01$  ; \*  $p < .05$

**Table 4** Multiple regressions with single tool use and pantomime of tool use as criterion and Alter., Assoc., Func. And Manip. As predictors for LBD patients

Criterion	Predictors	$\beta$	$t$	$p$
<i>Single Tool Use</i>				
	Alter.	.85	3.53	**
	Assoc.	.65	3.10	**
	Func.	-.72	-2.75	*
$F(3,17) = 14.75, p < .001, R^2 = .72, R^2_{adj} = .67$				
<i>Pantomime of Tool Use</i>				
	Alter.	.46	2.73	*
	Manip.	.46	2.74	*
$F(2,18) = 20.95, p < .001, R^2 = .70, R^2_{adj} = .67$				

Alter.: Alternative tool selection; Assoc.: Associative; Func.: Function;

Manip.: Manipulation

\*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$