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Pliers, not fingers: Tool-action effect in a motor intention paradigm

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ABSTRACT

Tool-use representations have been suggested to be supported by the representation of hand actions and/or by the representation of tool actions. A major issue is to know which one of these two representations is preferentially activated when people intend to use a tool. To address this issue, we developed a paradigm in which, in 20% of trials, participants had to press a button and actually use pliers to move an object in response to a predefined target symbol. Importantly, two masks hiding the symbols performed "opening" or "closing" actions before symbols appeared. In Experiment 1, participants used normal pliers: Hand's opening actions induced pliers' opening actions and vice versa for hands' closing actions. Results indicated a compatibility effect between masks' actions and pliers' actions. Participants were faster to press the button in response to the target symbol when opening and closing actions of the masks were congruent with the corresponding actions of the hand. In Experiment 2 participants used inverse pliers: Hand's opening actions involved pliers' closing actions and vice versa. In this situation, results showed that the congruency of masks' actions occurred with pliers' actions and not hand's actions. Altogether, these findings demonstrate that intention of use is preferentially based on the representation of tool actions, and have important implications for the domain of neuropsychology of tool use and the theories of goal-directed behavior.

1. Introduction

Different animal species use tools but humans are unique because they use tools frequently (Osiurak, Jarry, & Le Gall, 2010, 2011). So, a fundamental issue is to understand the psychological basis of human tool use. Tool-use representations have been suggested to contain two types of information, namely, information about the manipulation (e.g., Buxbaum, 2001) and the mechanical action of the tool (e.g., Goldenberg & Hagmann, 1998; Osiurak et al., 2010). For instance, when using pliers to grasp and move an object, manipulation-centered representations correspond with the hand's closing/opening action (hand-action effect) and mechanical-action-centered representations with the pliers' closing/opening action (tool-action effect). The aim of the present study is to explore which one of these representations is activated when people intend to use a tool.

According to the embodied cognition view, conceptual knowledge about tool use is grounded in sensorimotor representations (e.g., Barsalou, 1999; see also Binkofski & Buxbaum, in press). Evidence for this view comes from neuroimaging (e.g., Chao & Martin, 2000; Grèzes, Tucker, Armony, Ellis, & Passingham, 2003) as well as experimental studies showing that the mere observation of a tool is sufficient to activate motor representations of how to grasp and use them (Tipper, Paul, & Hayes, 2006; Tucker & Ellis, 1998). This view has found resonance in neuropsychology, wherein difficulties met by left brain-damaged patients with apraxia of tool use have been described as resulting from damage to stored representations about

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how to manipulate tools (Binkofski & Buxbaum, in press; Buxbaum, 2001; Rothi, Ochipa, & Heilman, 1991). In a way, these studies stress the role of hand-action effect representations in tool use.

An alternative theoretical position assumes that although there is a significant interaction between sensorimotor and conceptual representations, they are also dissociable (e.g., Chatterjee, 2010; Mahon & Caramazza, 2005, 2008). Retrieving conceptual knowledge about tool function (knowing the tool's usual function/mechanical action) may activate representations about manipulation, but the retrieval of conceptual knowledge does not necessarily imply the prior activation of those representations (e.g., Negri et al., 2007). In line with this, Garcea and Mahon (2012) demonstrated that participants presented with pictures of familiar tools were faster to make mechanical action/function judgments than manipulation judgments. Interestingly, apraxia of tool use has also been explained as resulting not from impaired representations about manipulation but rather from impairment at a conceptual level and, more particularly, to understand mechanical actions (Goldenberg, 2009; Goldenberg & Hagmann, 1998; Goldenberg & Spatt, 2009; Jarry et al., 2013; Osiurak, Jarry, Lesourd, Baumard, & Le Gall, 2013; Osiurak et al., 2008, 2009, 2010, 2011). In broad terms, these studies emphasize the role of tool-action effect representations.

When engaged in everyday life activities such as working odd jobs (e.g., to set up a shelf), we generally anticipate the future tool actions to perform (e.g., turning a screw with a screwdriver). In a way, the activation of the representations of these future tool actions forms the intention of use. So, as long as the relevant situation or event does not occur (e.g., the wooden board correctly placed) we maintain this intention (see Badets, Albinet, & Blandin, 2012, for a complete description of this event-based task of delayed motor intention). To better understand the psychological basis of human tool use, it appears interesting to determine whether this intention of use is preferentially based on hand-action effect or tool-action effect representations.

The aim of the present study was to address this issue. Generally used experimental paradigms do not allow us to do so because participants are commonly asked to form a covert intention of the use action and to directly execute the overt action. To bypass this methodological issue, we developed a motor intention paradigm wherein participants had to form an intention of use all along an ongoing task but to execute the overt action infrequently during the ongoing task and only in response to a specific stimulus (Badets et al., 2012; see also Einstein & McDaniel, 2005 for a review on this event-based task in the domain of prospective memory). More particularly, participants were instructed that they would use pliers to grasp and move an object. To know when they had to use the pliers, participants performed a computerized task wherein pairs of symbols were presented. In 20% of trials, a target symbol appeared indicating that they had to press a key and use pliers to move an object. We called these trials the action trials. When no target were presented, they had to respond whether the two symbols were similar or not (80% of trials; judgment trials). Two masks hid the symbols before their presentation. Those masks performed either an "opening" or a "closing" action before symbols appeared.

In Experiment 1, participants had to use normal pliers to move an object either by opening or closing the pliers to move the object (between-subjects condition). For these pliers, the hand action (opening/closing) was analogous to the tool action (opening/closing). As found in other paradigms (e.g., Tucker & Ellis, 1998), we expected to obtain in the action trials a compatibility effect between the hand/tool-action and the irrelevant masks' action. More specifically, we hypothesized that participants who made an opening hand/tool-action with the pliers responded faster to target symbols when preceded by opening than closing masks' actions. The opposite pattern was expected for the participants who made a closing hand/tool action with the pliers. We thought that for a closing hand/tool-action, for example, participants would form an intention of use based on the abstract code "closing". Thus, the congruency of this code with the masks' action would prepare the participants to overtly execute the use action, improving the detection of the target symbol. Given that the actions made by both the hand and the tool were analogous, we could not determine whether the intention of use was based on hand-action effect or tool-action effect representations. Therefore, in Experiment 2, participants had to use inverse pliers to move an object either by opening or closing the pliers to move the object (between-subjects condition). Importantly, for these pliers, the hand action effect was opposite to the tool action effect. So, as suggested by the manipulation hypothesis (Binkofski & Buxbaum, in press; Buxbaum, 2001; Rothi et al., 1991), if the intention of use was based on hand-action effect representations, a compatibility effect should be found between the hand action and the masks' action. By contrast, as suggested by the tool function hypothesis (Goldenberg & Spatt, 2009; Osiurak et al., 2010, 2011), a compatibility effect between the tool action and the masks' action should be observed if the intention was based on tool-action effect representations.

Finally, it is noteworthy that the use of two different pliers making different actions (opening vs. closing) is inspired from the study of Umiltà et al. (2008). They observed in monkeys trained to use tools that cortical motor neurons, active during hand grasping, also became active during grasping with pliers, as if the pliers were the fingers. This study showed that motor embodiment could occur after training. With regard to the study of Umiltà et al. (2008), the originality of the present study was to examine whether, without any training, people form an intention of use based on the abstract code linked to the action of the tool. In other words, the originality of the present study was also to extend the results of Umiltà et al. (2008) to human subjects.

2. Experiment 1

2.1. Method

2.1.1. Participants

Twenty-four undergraduate students from the University of Lyon took part in Experiment 1 (16 women; M_{age} = 19.38, SD_{age} = 0.82). All participants were