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Priming effects of words on tool visual exploration

Giovanni Federico^{1*}, François Osiurak^{2,3}, Maria A. Brandimonte⁴

¹ IRCCS SDN, Naples, Italy

² Laboratoire d'Etude des Mécanismes Cognitifs, Université de Lyon, Lyon, France

³ Institut Universitaire de France, Paris, France

⁴ Laboratory of Experimental Psychology, Suor Orsola Benincasa University, Naples, Italy

* **Correspondence concerning this article should be addressed to**

Giovanni Federico

IRCCS SDN, Naples

113, Via Emanuele Gianturco, 80143 Naples, Italy

E-mail: research@giovanfederico.net

Abstract

Most recent research on human tool use highlighted how people might integrate multiple sources of information through distinct neurocognitive systems in order to exploit the environment for action. This mechanism of integration is known as "action reappraisal" (Federico & Brandimonte, 2019; 2020). In the present eye-tracking study, we further tested the action reappraisal idea by devising a word-priming paradigm to investigate how thematically-consistent (e.g., "nail") vs. thematically-inconsistent words (e.g., "jacket") that preceded the vision of tools (e.g., a hammer) may affect participants' visual exploration of them. Results showed that tools' manipulation areas (e.g., the handle of a hammer) were fixated longer under the thematically-consistent (e.g., the word "nail" preceding a hammer) than the thematically-inconsistent condition (e.g., the word "jacket" preceding a hammer). Conversely, the tools' functional areas (e.g., the head of a hammer) received longer fixations under the thematically-inconsistent than the thematically-consistent conditions. These results support and extend the information-integrated perspective of the action reappraisal approach by providing further evidence about how higher-level, semantic information may influence tools' visual exploration.

Keywords

Tools, Words, Action Reappraisal; Semantic knowledge, Eye-tracking

1. Introduction

We live surrounded by objects. Some of these objects, generally called "tools", are very particular because they are built by us, humans, to meet our needs and achieve our goals. Tools expand our sensorimotor abilities (Osiurak, Jarry & Le Gall, 2010), hence allowing us to do things we could not do otherwise. For instance, by knocking a nail with a hammer to get it into the wall, we can hang a picture in the living room. In other words, through the hammer, we become able to modify our living space. However, despite linked to a mostly motor activity (e.g., hammering), human tool use should not be considered as a static and procedural activity. Indeed, we can use tools with extreme flexibility, as testified by our innate propensity to use tools even in uncommon manners (e.g., screwing a screw by using a knife) if we have to solve a problem (e.g., wall-mounting a shelf). Therefore, tool use can be easily regarded as an instance of a problem-solving situation supported by technical reasoning (Osiurak & Badets, 2016; see also: Beck, Apperly, Chappell, Guthrie, & Cutting, 2011).

Mainstream theories of human tool use – derived mainly from the embodied cognition approach (Barsalou, 2008) – strongly stress the motor aspects associated with tools by granting an exceptional role to the so-called *manipulation knowledge* (e.g., Thill, Caligiore, Borghi, Ziemke & Baldassarre, 2013). We manipulate tools and, as a consequence, we store information about how to manipulate them. Hence, as soon as we see a tool, we automatically activate motor simulations linked to how to manipulate it¹. In contrast, the central assumption of most recent "reasoning-based" theories is that we reason about the physical object properties to solve everyday life problems rather than passively learn relationships between objects and how to manipulate them (Goldenberg, 2013; Osiurak & Badets, 2016). Thus, by underlining the weight of the so-called *mechanical knowledge* (i.e.,

¹ According to the manipulation-based hypothesis, when we see a tool, we automatically activate two kinds of motor representations: How to grasp it (i.e., "structural affordances") and How to use it (i.e., "functional affordances"). By positing the automatic activation of motor representations associated with the tool's usual function (i.e., How to use it), the so-called automatic activation hypothesis of functional affordances is a crucial aspect of many embodied approaches to human tool use (see Thill et al., 2013 for a review).

technical reasoning)², the reasoning-based hypothesis considers humans as problem solvers who are able to transform their physical environment by making and using tools in common and uncommon ways (Osiurak, Lesourd, Navarro & Reynaud, 2020). To do that, we may integrate different kinds of information (e.g., semantic/mechanical knowledge associated with tools, physical principles, procedural memories, context-conveyed information, etc.) that are in turn processed by distinct neurocognitive systems (Federico & Brandimonte, 2019). Therefore, tool use is a complex and multidimensional phenomenon, hard to consider as descending from motoric automatisms. The objects of such complexity are easily identifiable in the extensive fronto-temporo-parietal brain networks constituting the neural correlates of human tool-use abilities (e.g., Goldenberg & Spatt, 2009; Orban & Caruana, 2014; Osiurak et al. 2017; Reynaud, Lesourd, Navarro & Osiurak, 2016). It is worth to remark how the integrated perspective of the reasoning-based approach might find strong support in recent evidence related to the identification of cortical areas that integrate distinct kinds of knowledge to form generalisable object representations (e.g., Chen, Garcea, Jacobs & Mahon, 2018; De Bellis et al. 2018; Wurm & Caramazza 2019; Lambon Ralph, Jefferies, Patterson & Rogers, 2017; see also: Rogers & McClelland, 2004; Bar et al. 2006).

Consistently with the reasoning-based approach and with the recently proposed Three-Action System (Osiurak et al., 2017), Federico and Brandimonte (2019, 2020) introduced the concept of "action reappraisal" referring to the way humans can dynamically use various sources of information to exploit the environment in terms of action. Precisely, the authors highlighted a semantic/mechanical-to-motor cascade mechanism through which humans, in a recursive way, first generate the mechanical actions to be executed by

² By using the term mechanical knowledge as a synonym of technical reasoning, we refer throughout the article to a form of knowledge about physical principles. Therefore, we intend a non-declarative kind of knowledge that has to be considered as abstract because physical and technical realities do not overlap. Indeed, a single physical matter (e.g., glass) can have distinct properties (e.g., hardness, sharpness, transparency). Conversely, distinct physical matters (e.g., metal or plastic) can have the same single property (e.g., hardness). Also, as happens in by-analogy problem-solving situations, we are able to quickly transfer the mechanical principles we learned through a specific tool or in a specific circumstance to another (e.g., a knife may be used to screw by transferring the function usually associated with a screwdriver to the knife). Most importantly, one of the peculiarities of human tool use lies exactly in transfer skills (e.g., Penn, Holyoak & Povinelli, 2008). Further discussions on these aspects may be found in Osiurak & Badets (2016).

integrating multiple kinds of information (i.e., semantic and mechanical knowledge), then they place constraints on the motor actions that have to be selected by the motor-control system to actualise the action (Osiurak, Federico, Brandimonte, Reynaud & Lesourd, 2020). The authors investigated how the above-mentioned interactions among neurocognitive systems associated with tool use reverberate on tools' visual-attentional patterns. Specifically, the authors analysed by eye-tracking the gaze behaviour of participants looking at single tools and object-tool pairs that could be thematically consistent (e.g., nail-hammer) or not (e.g., scarf-hammer). They found that, by considering the first 500ms of visual exploration, participants focused on tools' functional areas (i.e., the head of a hammer) in any experimental condition. However, extending the time window of analysis (≥ 1000 ms), participants focused on the manipulation areas of the tools (e.g., the handle of a hammer) when the visual scene prompted high action readiness (e.g., when a hammer was seen next to a nail). Contrariwise, when the visuoperceptual context was less action prompting (e.g., when a hammer was seen next to a scarf) or when a specific non-motoric task was used (i.e., looking at tools to recognise them), participants did not proceed toward a motor processing of the visual scene, hence remaining focussed on the functional areas of the tools (e.g., the head of a hammer). These results are in line with the idea that we use tools by processing multiple types of information (semantic/mechanical knowledge than sensorimotor information) to interact with the environment in a way that is consistent with our goals. Also, these results highlighted how the semantic/mechanical-to-motor cascade mechanism reverberate on the temporal allocation of visuospatial attention for tools.

Following such an information-integrated perspective, in this eye-tracking³ study, we further investigated the action-reappraisal idea by devising an experimental paradigm that

³ One might wonder why we chose to perform an eye-tracking study rather than a typical tool-related task. Here is therefore useful to remind that the most basic assumption of the direct-visual-route-to-action view is that vision guides action (Milner & Goodale, 2008). In particular, it has been repeatedly underlined how the “implicit recognition of action-related object attributes [affordances] can bias object competition – and visual spatial attention” so that “the motor affordance of an object must first be recognized, a process that likely involves attention to specific object features” (Handy, Grafton, Shroff, Ketay & Gazzaniga, 2003, p. 424-425). Thus, we can reasonably assume that the temporal allocation of visuo-spatial attention reflects visually guided behaviour. If an action-related object attributes is

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combined tools with different but semantic-by-default information: Words. Therefore, we developed a word-priming paradigm in which thematically-consistent (e.g., "nail") or thematically-inconsistent words (e.g., "jacket") preceded the vision of single tools (e.g., a hammer). We hypothesised that, as an effect of the action reappraisal mechanism (Federico & Brandimonte, 2019, 2020), the thematic consistency of words used as priming stimuli should modulate tool-use propensity hence affecting tools' visual-exploration patterns. We expected participants implicitly use prime words (i.e., semantic-related stimuli) as a source of information to guide the tool's visuospatial exploration. Hence, we conjectured that the prime words adopted in this study should act as the objects of the object-tool pairs used in Federico & Brandimonte (2019, 2020). In other words, we instrumentally used thematically consistent and thematically inconsistent words to manipulate the action readiness of the visuoperceptual context, hence exploring for the first time how participants integrate different classes of information as a result of the action reappraisal mechanism. On this basis, we posited that, by using a long-time window of analysis (i.e., 1.000ms), the manipulation areas of the tools should be fixated longer under the thematically-consistent (e.g., the word "nail" preceding a hammer) than the thematically-inconsistent condition (e.g., the word "jacket" preceding a hammer), as to indicate a higher propensity to use tools. In fact, within the higher action-readiness visuoperceptual context prompted by the thematically-consistent prime words, participants should proceed faster in the semantic/mechanical-to-motor cascade mechanism, hence finalising the motor processing of tools (i.e., preparing to grab the tool in order to use it, hence fixating longer its manipulation area). Conversely, within a lower action-readiness context (i.e., thematically-inconsistent condition), tools' functional areas (e.g., the head of a hammer) should obtain longer fixations, possibly due to the non-finalisation of the cascade mechanism (Federico & Brandimonte, 2019, 2020).

perceived, the fixation pattern of the object will be mostly focused on its action-relevant parts (Handy et al., 2003; Land, 2006; Roberts & Humphreys, 2011; Natraj, Pella, Borghi & Wheaton, 2015; Ambrosini & Costantini, 2017). Consistently with that, the temporal allocation of visuo-spatial attention to specific areas of tools (e.g., the handle of a screwdriver) can be effectively used as an indirect index of action-readiness prompted by the visuoperceptual context (Federico & Brandimonte, 2019).

2. Method

2.1. Participants

Thirty-five (18 females; mean age = 26.69 years, S.D. = 6.22) right-handed participants were recruited for the study. The sample size was calculated on the basis of a similar study (Federico & Brandimonte, 2019) and by conducting an a-priori power analysis (Faul, Erdfelder, Lang & Buchner, 2007) to detect a small effect size ($\eta_p^2 = .20$) within a repeated-measures ANOVA, with a power of .80 and an alpha level of .05.

2.2. Materials

We designed by computer graphics ten 3D colour images for the experiment. Each image depicted a single tool placed on a table that appeared within the peri-personal space of the participant. There were the following ten tools: hammer, knife, screwdriver, pen, whisk, bottle opener, bottle, key, spoon, cutter. We used two groups of Italian words in the experiment, both populated by ten object names. These words could be thematically consistent with the tool (e.g., the word "nail" for the "hammer") or not (e.g., the word "printer" for the "bowl"). The two groups of words, therefore, constituted the two experimental conditions of the study. The first group (i.e., thematically consistent) was composed by the following words: nail, salami, screw, notebook, bowl, beer, glass, lock, cup, carton. The second group of words (i.e., thematically inconsistent) comprised: jacket, racket, hat, sock, printer, telephone, headset, photo, stove, nut. All the stimuli and words used in the experiment are illustrated in *Figure 1*.

Figure 1 about here

2.3. Procedure

The study was executed in the Laboratory of Experimental Psychology of the Suor Orsola Benincasa University of Naples (Italy). The study was approved by the Ethics Committee of the Suor Orsola Benincasa University and was fully compliant with the ethical standards of the Helsinki Declaration (1964). Written informed consent was obtained from each

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participant before starting with the experiment. Right-handedness, the absence of neurological/psychiatric diseases and the adequate visual acuity were self-reported by every participant before starting the experiment. Participants were invited to sit on a chair, placing their chin on a chinrest. In this way, they were at a distance of about 54cm from a 23-inches monitor. We asked participants to keep their hands motionless on the desk. Then, an eye-tracking calibration procedure was administered. At the end of the calibration, the experimental instructions appeared on the screen, and the experiment started. The task was to "observe what appeared on the screen in the most natural way as possible". Ten images, each preceded by a word, were administered for each condition. Hence, given the within-participants experimental design, twenty images randomly appeared on the screen, each preceded by a word that could be thematically consistent with the tool depicted in the image (e.g., the word "nail" for a hammer) or not (the word "jacket" for a hammer). Words appeared for 1000ms, whereas images appeared for 6000ms. Each stimulation (word and image) was preceded by a fixation point (500ms). Each image was succeeded by a black screen (4000ms) to permit participants' eyes (retina) to relax. Single stimulation (word + image) lasted 9000ms. Overall stimuli presentation lasted 3 minutes. The experimental visual flow is summarised in *Figure 2*. The overall duration of the experiment was approximately 15 minutes for each participant. At the end of the experiment, all participants were debriefed about research objectives and methodologies. No participant was excluded from the sample.

[Figure 2 about here](#)

2.4. Apparatus

We collected eye-tracking data by using a Full-HD Webcam (Logitech HD Pro C920) with a sampling rate of 60Hz. We used the RealEye.io platform to design the experiment and to register gaze-behaviour data. The eye-tracking technologies involved in the experiment are based on WebGazer (Papoutsaki et al., 2016). A 23-inches monitor (with a resolution of 1920*1080px) was used as a stimulus presentation device.

2.5. *Eye-tracking data*

Participants' visual-attentional patterns were analysed in terms of mean fixation time to two specific Areas of Interest of the tools (AOIs). In particular, we considered the Manipulation Area of the tool (i.e., the middle-bottom area where to put the hand to use the tool) and the Functional Area of the tool (i.e., the middle-top area through which it is possible to recognise its identity). An example of the AOIs analysed in the study is shown in *Figure 3*. The mean fixation time to the AOIs was averaged for both experimental conditions. For each stimulus, we excluded the eye-tracking data related to the first 250ms to mitigate the error generated by the initial fixation point in the visual-exploration patterns of the participants. Then, we analysed only the first 1000ms of visual-exploration data for each stimulus. We chose this time window to decrease data dispersal effects due to the exploration of the visual scene by participants (Federico & Brandimonte, 2019, 2020). A qualitative indication of differentiation in participants' visual-attentional patterns may be observed by looking at the fixation heatmaps (*Figure 4*).

[Figure 3 and Figure 4 about here](#)

2.6. *Data analyses*

To examine how participants looked at the tools as an effect of word priming, we performed a 2 x 2 repeated-measures analysis of variance (RM-ANOVA) with AOIs (Functional vs. Manipulation Area of the tool) and Thematic Consistency (thematically-consistent words vs. thematically-inconsistent words) as 2-level factors on tools' mean fixation duration (expressed in milliseconds, time-window of analysis: 1000ms). An alpha level of .05 was used. For multiple comparisons, we used the Tukey HSD test. We performed the statistical analysis by using the open-source software "R" for Apple macOS 11. Data of two participants (2 females) were considered outliers and deleted (measures above 2.5 SD).

3. Results

The RM-ANOVA revealed a significant interaction of AOIs and Thematic Consistency, $F(1, 32) = 32.38$, $p < .001$, $\eta^2 = .50$. Post-hoc pair-wise comparisons revealed that the mean fixation duration for the manipulation AOIs was longer in the thematically-consistent condition than the thematically-inconsistent condition ($p < .001$). Instead, the functional AOI was fixated longer in the thematically-inconsistent than the thematically-consistent condition ($p = .012$). Within the thematically-consistent condition, the manipulation AOI was fixated longer than the functional AOI ($p = .029$) whereas in the thematically-inconsistent condition the functional AOI was fixated longer than the manipulation AOI ($p = .047$). The interaction is shown in *Figure 5*. No main effects of AOIs or Thematic Consistency were found.

Figure 5 about here

4. Discussion

In this study, we analysed the visual exploration patterns of participants engaged in a word-priming task in which they looked at tools preceded by either thematically-consistent or thematically-inconsistent words. Consistently with our predictions, participants fixated the manipulation area of the tools longer under thematically-consistent than thematically-inconsistent condition. Thus, when the word "salami" preceded the vision of a knife, participants tended to look at the handle of the knife longer as compared to when the word "racket" anticipated the same knife. In a certain way, the thematically-consistent words presented just before tools administration may have generated a higher action propensity that was thereby reflected in a visual-attentional pattern coherently associated with the graspability and the usability of the tool. Crucially, when participants were primed with thematically-inconsistent words, they exhibited a reversed visual-attentional pattern with tools' functional areas being fixated longer than manipulation ones. Thus, consistently with our previous findings (Federico & Brandimonte, 2019, 2020) but combining a totally new kind of semantically based information (i.e., words and tools), these results provide further

evidence of how higher-level, semantic information may influence the visual exploration of tools.

Such an action-propensity modulation is difficult to interpret by assuming the primacy of motor processing in human tool use. Indeed, within such a manipulation-based perspective (e.g., Thill et al., 2013), the vision of a tool automatically activates the motor representations associated with how to grasp it (also called as "structural" affordances) and how to use it (also called as "functional" affordances; see Osiurak et al., 2017 for a comprehensive discussion about the multitude meanings of the word "affordance"; see also note 1). Consequently, the temporal allocation of visual-spatial attention to the manipulation area of tools, being associated with its usability (e.g., Bub, Masson & Cree, 2008), should not vary so much between experimental conditions. Therefore, the question that arises is how to interpret these results within an alternative theoretical framework.

As stated above, most recent theories in the field of tool use have started to move away from the manipulocentric perspective of the neuropsychology of action (e.g., Thill et al., 2013) as it may produce the belief that humans are mere "manipulators", hence under-intellectualising such a characterising human ability (Osiurak & Federico, 2020). Being no more considered as manipulators, humans are thereby seen as problem solvers that reason to adapt the environment to their needs (Osiurak et al., 2020a). Within the reasoning-based perspective, we do not automatically activate the manipulation knowledge of a tool to use it just because we merely see it. Instead, based on the physical problem we intend to solve, we reason about the most appropriate way to use the tool(s) to reach a goal. To do that, we use the so-called *mechanical knowledge*, that is, a non-declarative form of knowledge about physical principles (i.e., technical reasoning; Osiurak & Badets, 2016; Osiurak et al., 2017; see also Goldenberg, 2013; see also note 2). Whereas mechanical knowledge is directly implicated in tool-use behaviour (e.g., Osiurak et al. 2008; Goldenberg & Spatt, 2009), we may also integrate semantic knowledge to construct object-related representations that can be spent in the context of a cognitive-oriented functioning (Federico & Brandimonte, 2020). For instance, semantic knowledge may be useful to inform us about the common use of

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single tools, thereby enabling us to indirectly generate mechanical actions through the recruitment of mechanical knowledge (e.g., Osiurak, 2014). Under the reasoning-based hypothesis, the motor-control issue is therefore considered as the last step of a semantic/mechanical-to-motor cascade reiterative mechanism for which an agent first generates the mechanical actions to be performed by integrating, if necessary, distinct kinds of information, and then places constraints on the motor programs (e.g., reaching, grasping) to be selected by the motor-control system (for a detailed discussion on the temporal dynamics of tool use, see Osiurak et al., 2020b). Thus, being primed with words that were thematically associated with the tools (e.g., the word "nail", then a hammer), participants may have solved the semantic/mechanical issue easier, hence coming to the motor step of the cascade mechanism faster. To date, motor processing was reflected in a fixation pattern that emphasised the manipulation area of the tools in order to actualise the action. In contrast, when the words were thematically inconsistent with the tools (e.g., the word "sock", then a pen), participants may have lingered in the semantic/mechanical issue (How to use a pen with a sock?) hence not proceeding toward the motor processing (i.e., lower fixations to the tool's manipulation area and an increase of fixations to the functional area of the tool).

By replicating the results of Federico & Brandimonte (2019, 2020) with a different class of stimuli (words, instead of objects, that can be thematically consistent/inconsistent with tools), these results provide further evidence about the implications of an integrated perspective of tool use. Indeed, the fact that words, a kind of stimulus that is semantic by default, produced such a strong effect in the way participants looked at the tools is consistent with the action reappraisal idea introduced by Federico & Brandimonte (2019). In fact, the authors proposed that tool-use human abilities and, more generally, object representations, may be considered as a product of the integration between distinct types of information that are in turn processed by multiple and interconnected neurocognitive systems. Indeed, the integrated and reasoning-centred theoretical framework we summarised here recognises as neural correlates a significant and composite interplay of fronto-temporo-parietal networks (e.g., Orban & Caruana, 2014; Reynaud et al., 2016). In

particular, the recently-introduced Three-Action System (Osiurak et al., 2017) identifies as neural correlates of the mechanical knowledge the "PF" cytoarchitectonic area (Caspers et al., 2006) of the supramarginal gyrus (SMG), within the left inferior parietal cortex. Consistently with the idea of a cascade mechanism, such a ventro-dorsal system appears to be a kind of bridge between the semantic system related to tools' identity and functions (i.e., the ventral system) and the motor-control dorso-dorsal system (Osiurak et al. 2017). Additionally, the "Pft" cytoarchitectonic area, as part of the anterior portion of the SMG, seems to integrate information between mechanical knowledge and the motor-control system (Osiurak et al., 2017; Reynaud et al., 2016). Also, in line with the integrative perspective, recent and increasing evidence found in the inferior parietal cortex and the middle temporal areas an integrative layer associated with the generation of object-related action representation (e.g., Chen et al., 2018; De Bellis et al. 2018; Lambon Ralph et al., 2017; Wurm & Caramazza 2019).

Finally, when considering the involvement of frontal and prefrontal cortex in human tool use (specifically in action planning and execution; Reynaud et al., 2016), it appears how these areas might be easily related to the problem-solving-oriented perspective of the reasoning-based approach. Indeed, frontal-lobe areas are actively implicated in high-level executive functions as well as in motor timing, sequencing and simulation (e.g., Koechlin & Summerfield, 2007; Bortoletto & Cunnington, 2010). However, whereas the integration processes involving temporoparietal brain areas have been increasingly investigated, the frontal and prefrontal areas involvement did not get the same popularity. This might be due to the absence of a clear-cut neuropsychological correlation between tool-use impairments and frontal lesions. Notwithstanding, these areas might actively take part in the action-reappraisal mechanism as they may signal an inhibitory mechanism through which a reasoning-based agent, from the multiple environment-available action possibilities, may select only those that are consistent with their intentions. Intriguingly, neuropsychological evidence from patients with anarchic hand and/or utilisation behaviour due to frontal lesions (eg, Bakheit, Brennan, Gan, Green & Roberts, 2013; Lagarde et al., 2013; Lhermitte, Pillon

& Serdaru, 1986; Lhermitte, 1986) might be particularly useful in delineating possible new research directions about the degree of frontal-cortex involvement in tool-related reasoning processes.

To sum up, by providing further evidence for the action reappraisal mechanism (Federico & Brandimonte, 2019, 2020), the results presented here support the information-integrated perspective at the root of reasoning-based theories of human tool use. The action reappraisal idea and the reasoning-based hypothesis may constitute a reliable alternative to the manipulation-based approach, thereby giving us the possibility to expand our gnoseological horizons about the cognitive foundations of human tool use. In fact, as we introduced above, by focusing attention mainly to the prehensile component, the most critical limitation of the manipulation-based hypothesis is that it might induce us to under-intellectualise the cognitive bases of human tool use (Osiurak & Federico, 2020). Such a limitation is not cognitive-science specific as it can be found in other research domains such as archaeology or anthropology (see Osiurak & Reynaud, 2019 for discussion). Additionally, multiple studies have repeatedly shown how people may focus on the goal component of the action more than on its manipulative component (e.g., Massen & Prinz, 2007; Osiurak & Badets, 2014). Such a peculiar pattern has also been highlighted in observational studies where participants looked at a model using a tool (e.g., Decroix & Kalénine, 2018, 2019; Naish, Reader, Houston-Price, Bremner, & Holmes, 2013; Nicholson, Roser, & Bach, 2017; van Elk, van Schie, & Bekkering, 2008). Crucially, those studies explored the goal component in terms of functional areas of the tools and objects associated with them, hence implicitly referring to the mechanical actions generable by pairs of objects. Nevertheless, the results are often interpreted within the manipulation-based framework, perhaps because of the absence of an alternative framework. In this sense, the action reappraisal idea and, more generally, the reasoning-based approach, might be useful to generate alternative and viable theoretical frameworks.

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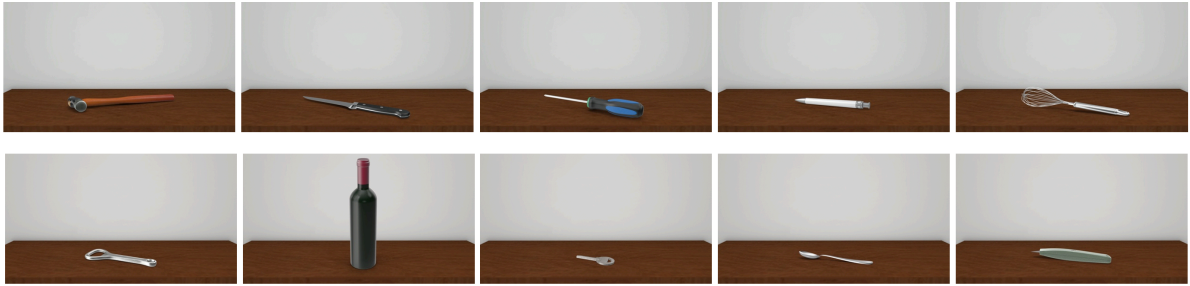
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WORD PRIMING AND TOOL VISUAL EXPLORATION

Tools



Words

Thematically consistent: NAIL, SALAMI, SCREW, NOTEBOOK, BOWL, BEER, GLASS, LOCK, CUP, CARTON

Thematically inconsistent: JACKET, RACKET, HAT, SOCK, PRINTER, TELEPHONE, HEADSET, PHOTO, STOVE, NUT

Figure 1: Tools and words used in the experiment

Ten 3D colour images depicting a single tool were used in the experiment as stimuli: a hammer, a knife, a screwdriver, a pen, a whisk, a bottle opener, a bottle, a key, a spoon, and a cutter. We used two groups of words as priming stimuli. The words could be thematically consistent or thematically inconsistent with the tools.

WORD PRIMING AND TOOL VISUAL EXPLORATION

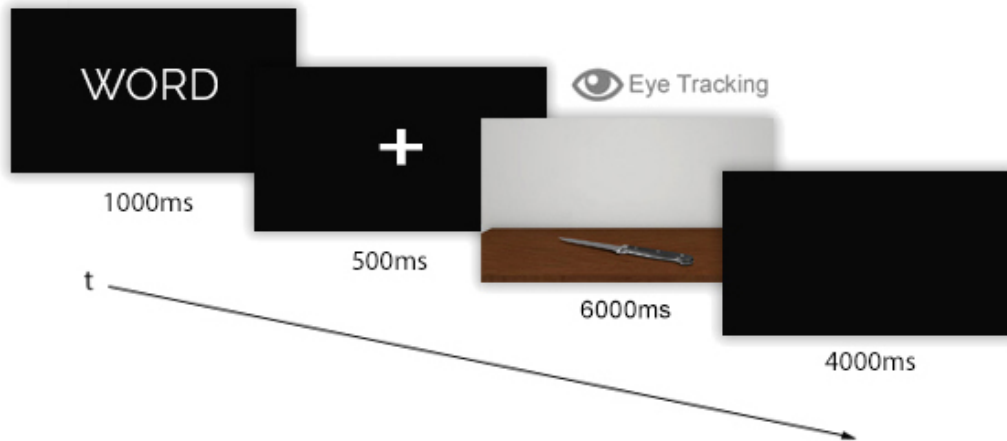


Figure 2: Experimental flow

A prime word was shown for 1000ms followed by a fixation point (500ms). Then, a tool image that remained on screen for 6000ms. Finally, a black screen appeared for 4000ms.

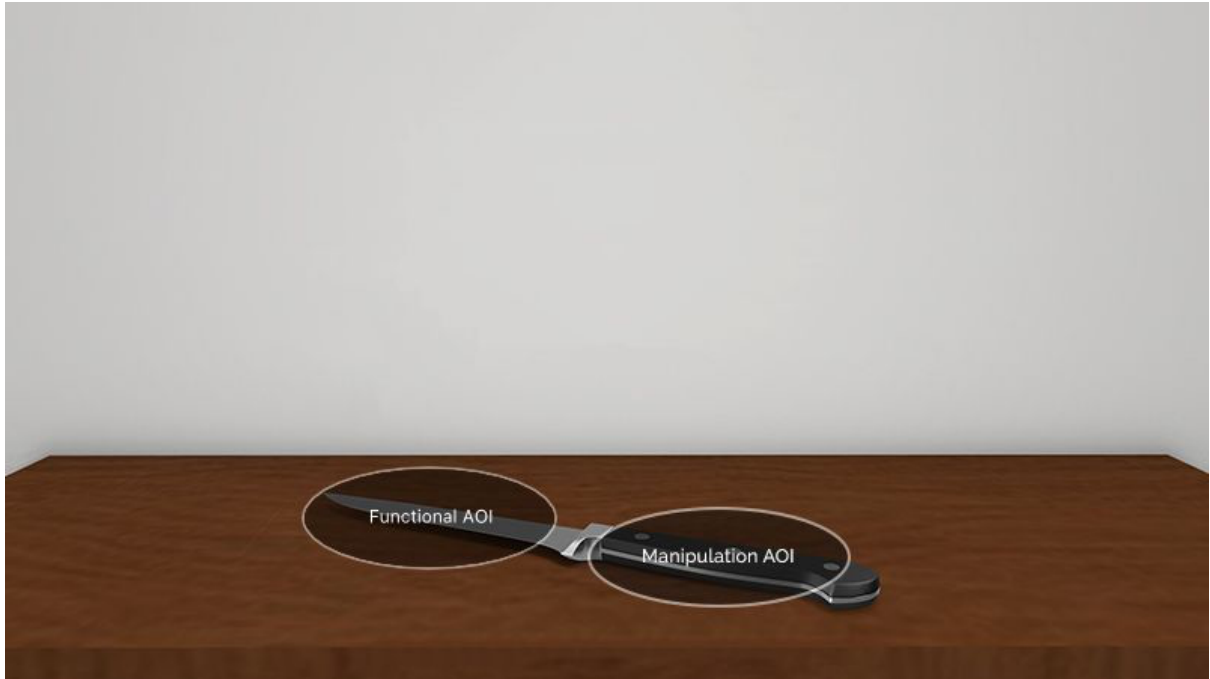


Figure 3: The Areas of Interest (AOIs) analysed in the study

The AOIs analysed in the study were the Manipulation Area and the Functional Area of the tool (circled and labelled).

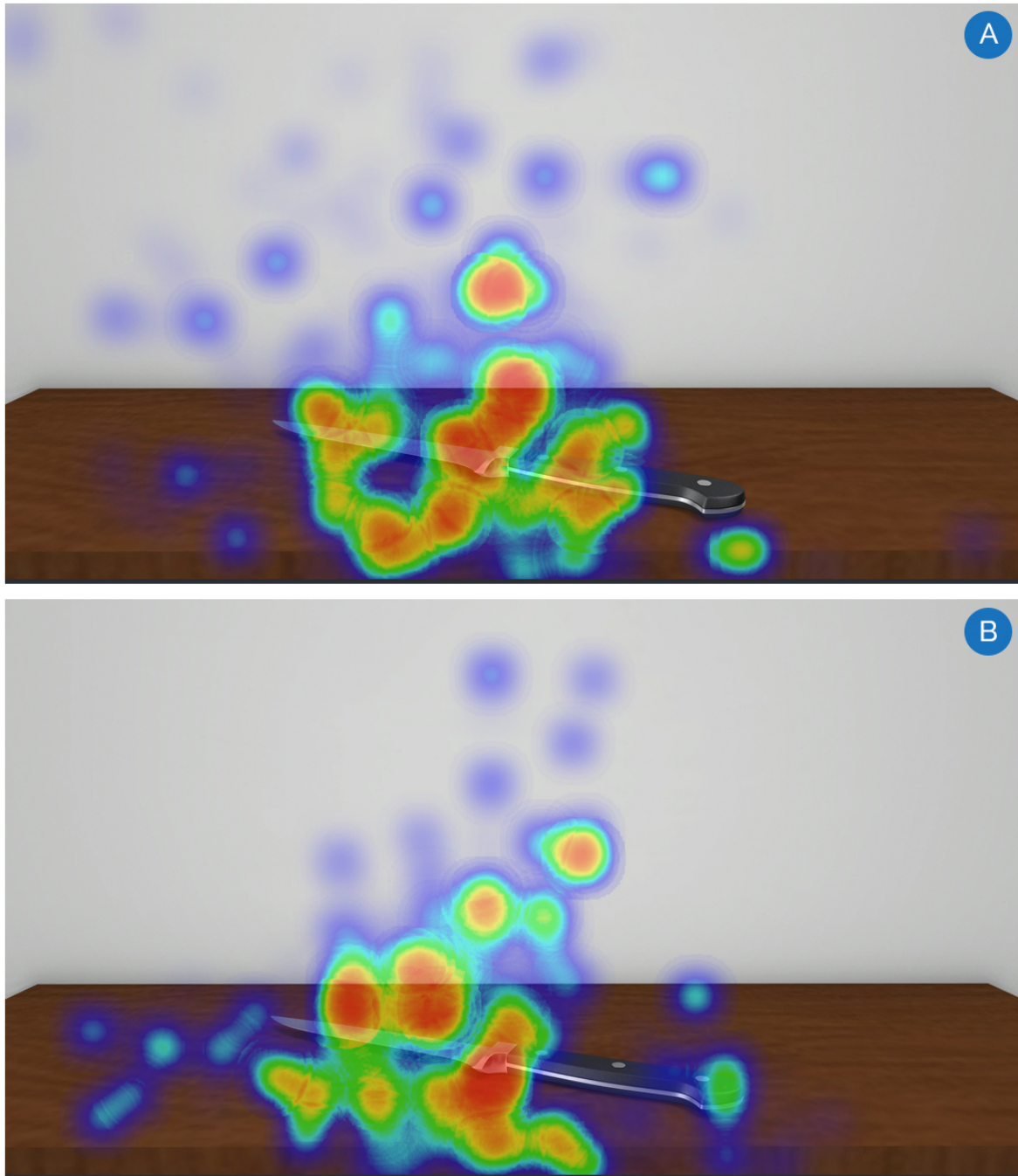


Figure 4: Visual exploration heatmaps

(A) A heatmap of a tool (knife) that was preceded by a thematically-consistent word (salami).

(B) A heatmap of a tool (knife) that was preceded by a thematically-inconsistent word (racket). Time window of eye-tracking data: 1000ms.

WORD PRIMING AND TOOL VISUAL EXPLORATION

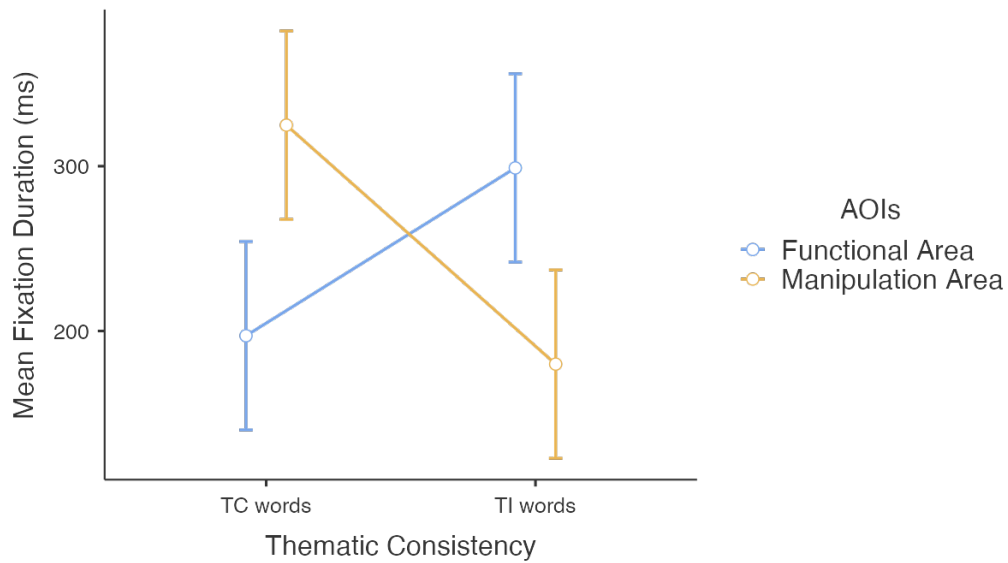


Figure 5: The effect of word priming on tool visual exploration

In the thematically-consistent condition, tools were longer fixated in their manipulation area, whereas in the thematically-inconsistent conditions, the tools' functional area was fixated longer. Vertical bars denote .95 confidence intervals. TC = Thematically Consistent. TI = Thematically Inconsistent.