Planning functional grasps of tools.
What can eye movements tell us about motor cognition?

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INTRODUCTION

Tools are a special category of objects: their visual structures (affordances), and the perceived functional identities are thought to **automatically "potentiate" relevant actions** (e.g., Creem-Regehr & Lee, 2005; Michałowski &Króliczak, 2015) – **including proper eye movements** (Desanghere & Marotta, 2011) – even in the absence of overt tasks (cf. Belardinelli at al., 2015). We tested this idea directly by asking subjects, who already participated in three experiments using the same sets of stimuli and tool–related tasks, to freely view these objects or to watch them with a view to planning functional grasps of these tools.
We hypothesized that watching with function in mind would result in more focused exploration of graspable parts.

METHODS

Participants

Twenty six right-handed university students (13 females) between the ages of 19 and 25 years (mean age of 21.7 years; SD=1.6) were tested. All participants had normal or corrected-to-normal vision. Their handedness was determined by a modified version of the Edinburg Handedness Inventory (Oldfield 1971).

Stimuli

The stimuli were high-resolution photos of workshop, kitchen and garden tools (Figure 1.) presented at three different angles (0º, 135º and 225º) in their foreshortened perspectives emulating 3D viewing. Two of the object orientations (135º, 225º) afforded an easy-to-make functional grasp, and the 0º orientation would result in a hard to perform functional grasp. The stimuli were randomized differently for the two tasks.

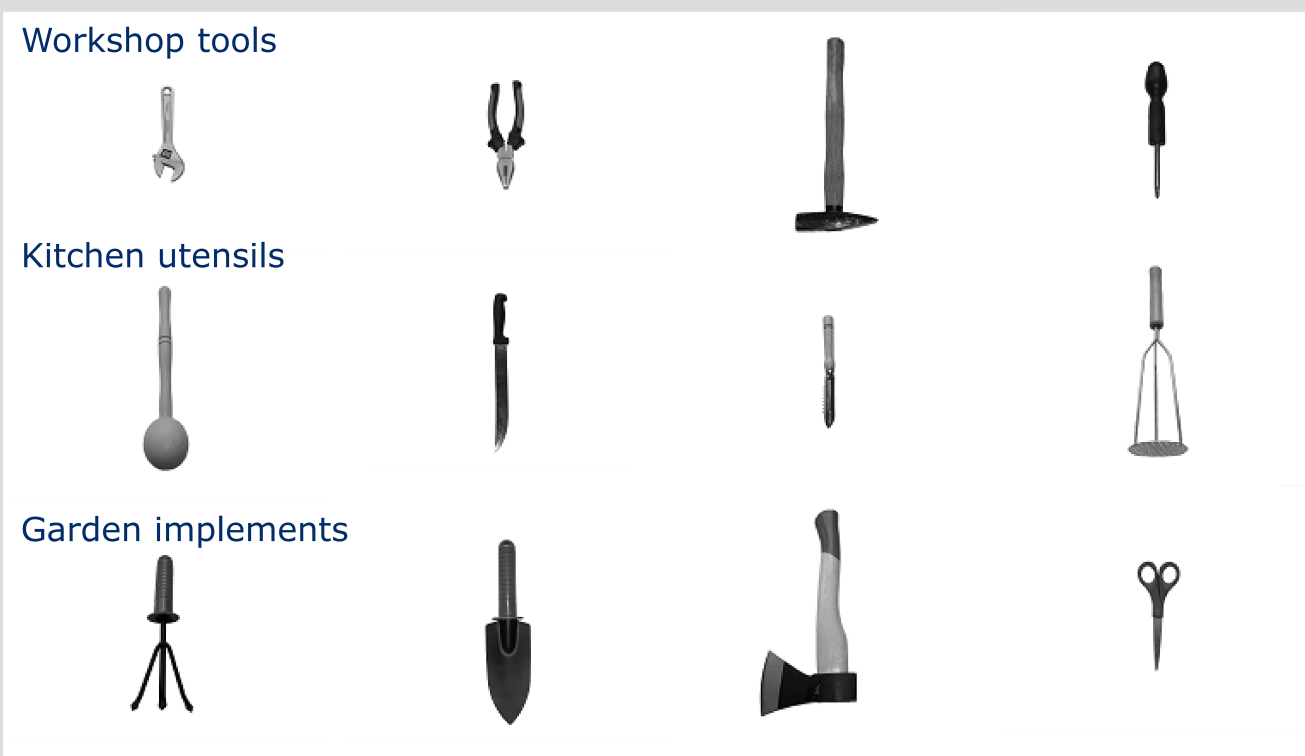


Figure1. *Examples of stimuli used in our experiment.*

Apparatus and Procedure

Participants were seated in a comfortable armchair and viewed a computer monitor. The viewing distance was ~ 57 cm. Eye movements were recorded by *RED*, SensoMotoric Instruments GmbH (SMI) eye-tracker (60 Hz sampling rate, spatial resolution < 0.5º).
The whole study consisted of two tasks: (1) free viewing; (2) viewing to plan functional grasp. Two Areas of Interest (AOIs) were defined: the graspable and executive (functional) part.

RESULTS

There was a main effect of AOI (F(1,14)=45.0, p<0.001), such that during free viewing fixations were distributed more equally across the graspable and functional parts (as compared to the grasp planning task). This effect – linked to the number of fixations and their spread into the two AOIs in the two tasks (including 3 exploration phases) - is visualized using a single object in Fig. 2 and Fig. 3.

Task No. 1 - FREE VIEWING

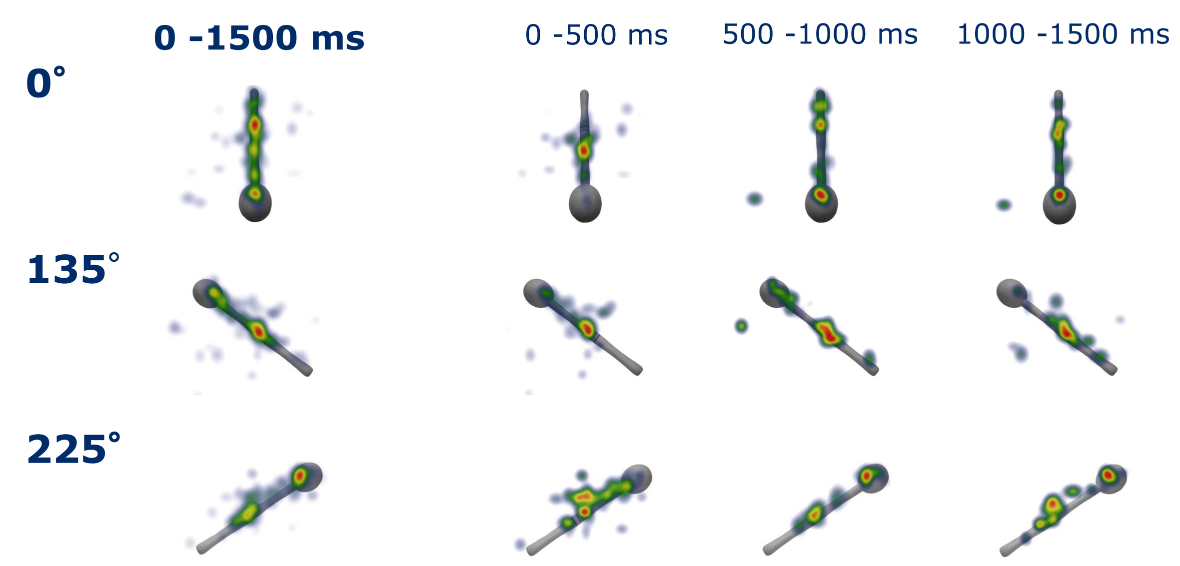


Figure 2.*The pattern of eye movements directed at the same object at 3 orientations when the participants were instructed to freely view the tools presented on the screen.*

Task No. 2 - FUNCTIONAL GRASP

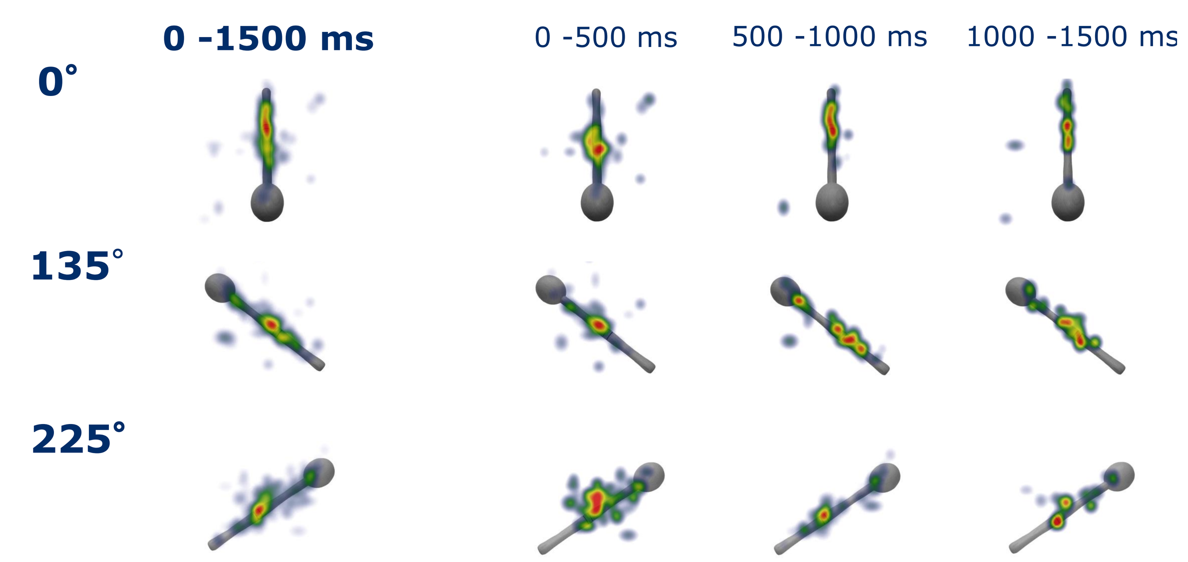
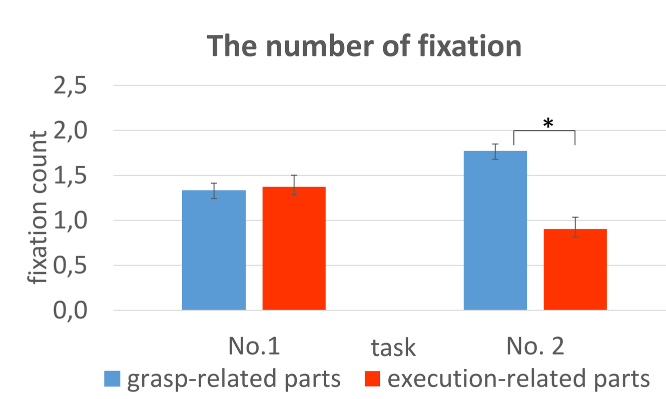
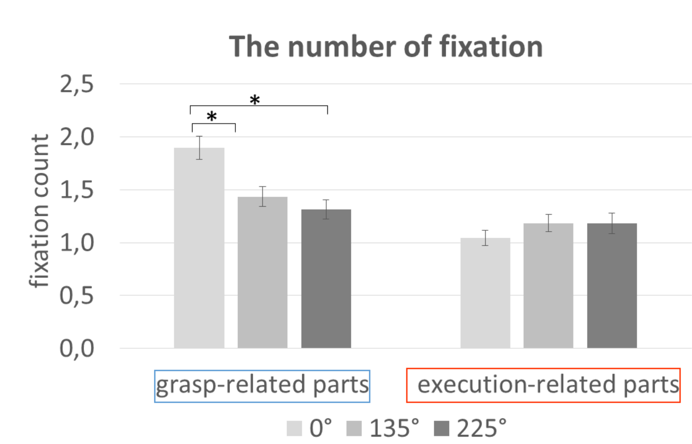


Figure 3.*The pattern of eye movements directed at the sesame objects when the participants were instructed to watch these tools with a view to planning functional grasps.*



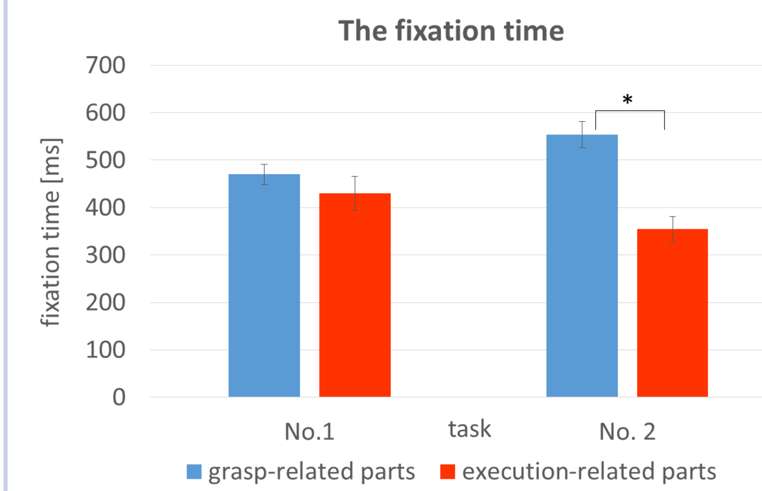
There was an interaction between task and AOI (F(1,25)=22.269; p<0.001), such significantly greater fixation count was observed for the graspable part in *the functional grasp* condition, while the number of fixations was distributed equally across AOIs in free viewing. This effect is shown in Fig. 4

Figure 4.*The number of fixation as a function of task and AOI.*



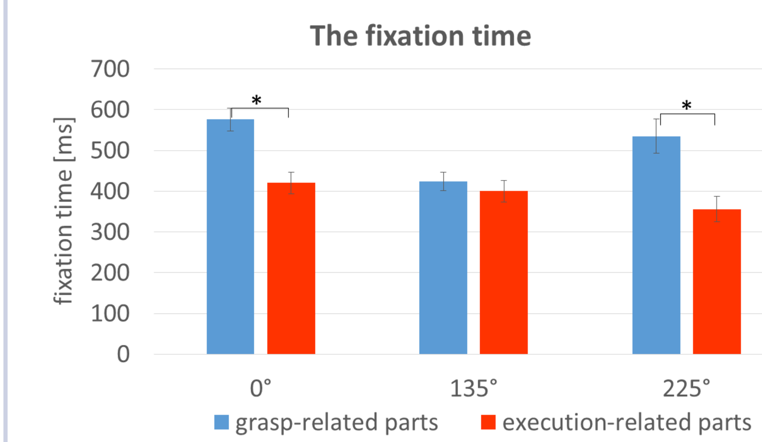
There was also a significant interaction between AOI and object orientation (F(2,50)=19.925, p<0.001), such that the graspable parts of tools shown at 0º were fixated (number of fixations) significantly more often.

Figure 5. *The number of fixation as function of stimulus angle.*



An interaction between task and AOI (F(1,25)=24.031; p<0.001) was also significant for fixation time, and it was such that graspable parts of tools were observed much longer during grasp planning, while the fixation time was distributed equally across AOIs (grasp- and execution-related parts) in free viewing. This effect is shown in Fig. 6

Figure 6. *Fixation time as a function of task and AOI.*



Finally, there was a significant interaction between task and viewing angle (F(2,50)=5.543, p<0.01), such that the graspable parts of objects shown at of 0º and 225º were fixated (visually explored) much longer when the task was to watch with a view to planning functional grasping, whereas the in the easiest 135º both AOIs were explored equally long. This effect is shown in Fig. 7.

Figure 7. *Fixation time as a function of the viewing angle (tool orientation) and AOI.*

DISCUSSION

The way common tools are visually explored in everyday live is believed to depend on whether or not object affordances are automatically perceived and, therefore, potentiate relevant actions. This process was thought to be independent of internal representations of tools. If this were the case then the eyes should be spontaneously directed either towards the grasp-related or execution-related parts of the studied objects. This was not the case.

When tools were viewed freely, the fixations and gaze durations were distributed equally across different parts of these objects. On the other hand, when object functions were taken into account, the graspable parts were more extensively viewed. In other words, participants did not pay much attention to the execution-related parts when affordance discrimination was critical for task performance.

These results clearly show that even the visual exploration of tools is sensitive to specific tasks (cf. Belardinelli et al. 2016), and other factors must contribute to automatic action potentiation in the presence of tools.

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HANDOUT

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