Interference from multiple affordances when selecting everyday graspable objects: thematic relations solve it.

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Abstract

Object perception and action are closely interrelated: various grasping components are evoked when perceiving visual objects ("object affordances"). Yet little is known about the impact of the evocation of multi-object affordances on object perceptual processing. This study aimed to determine whether object processing may be affected by the similarity of affordances evoked by multiple objects and whether semantic relations between objects modulate this effect. Adult students were presented with 3D scenes involving pairs of graspable objects. Each object evoked grasp size affordances (precision or power grasps). Affordances of the two objects could be similar or dissimilar and objects could be thematically related (spatula-pan) or unrelated (spatula-snow globe). Participants had to judge the color of a target object by performing power and precision grasps compatible or incompatible with the target evoked grasp. Results showed slower responses on compatible targets when unrelated distractors evoked similar compared to dissimilar affordances. This cost of similar affordances disappeared when objects were thematically related. Findings corroborate predictions of recent models hypothesizing automatic inhibition of distractor affordances when selecting one object among others. We further provide novel evidence for a role of thematic relations between objects in the perception of multiple affordances. Findings have implications for object processing in naturalistic scenes.

Keywords

object selection; grasp size affordances; 3D visual scenes; thematic relations; perception-action relations.

Public significance statement

This study shows the influence of action on perceptual processing of objects. It is more difficult to identify the visual properties of an object when the neighboring objects have similar action properties (e.g., spatula-snow globe). This difficulty vanishes when objects can be directly used together (e.g., spatula-pan). This suggests that in natural settings, the ability to select and process a familiar object depends on the action possibilities offered by the other objects present in the visual environment.

1- INTRODUCTION

When sitting at a breakfast table, one may be exposed to different objects offering different action possibilities: a glass of water can be grasped to drink, or a sugar cube can be grasped and dropped into a coffee cup. Depending on the intended action, it is necessary to select a specific target object among all the objects present in the scene. For example, if you are thirsty and want to drink, you must choose the glass instead of the sugar cube on the kitchen table. In this case, the sugar cube, which is not relevant to the task, can be considered a distractor for the target object, the glass. The general aim of the present study is to evaluate whether and how the presence of the distractor - the sugar cube - can interfere with the processing of the target- the glass.

Classical studies investigating the influence of distractor stimuli on target identification have shown that response times are slower when distractor and target with dissimilar *visual* properties (e.g., different letters) are associated with different responses (Eriksen & Eriksen, 1974). However, visual properties may not be the only type of distractor features that can interfere with response selection during target identification. Motor properties of distractors may also impact responses to a target object. In the previous example, the grasp action evoked by the sugar cube may interfere with the grasp action required to pick up and drink from the glass. The evocation of grasping components from visual objects was first demonstrated in the cognitive psychology literature by Ellis and Tucker (2000) and Tucker and Ellis (1998). Such affordances of manipulable objects have been defined as *"the motor patterns whose representation of visual objects and their properties give rise to"* (Tucker & Ellis, 1998, p. 833). In this view, the visual perception of an object would lead to the activation of action representations corresponding to how the observer would interact with the object. Numerous behavioral and neurophysiological studies, employing various paradigms, have provided evidence for the existence of object affordances (Borghi et al., 2007; Bub et al., 2015;

Derbyshire et al., 2006; Ellis & Tucker, 2000; Fairchild et al., 2021; Kalénine, Bonthoux, et al., 2009; Marini et al., 2019; Proverbio, 2012; Tucker & Ellis, 2001; Wamain et al., 2016). Depending on object's size and orientation, different affordances may be evoked: the orientation of an object may evoke hand effector affordances (Bub et al., 2015) or wrist orientation affordances (Ellis & Tucker, 2000), while object size may evoke grasp size affordances (Ellis et al., 2007). For instance, considering for example grasp size affordances, perceiving a glass may evoke a power grasp, whereas perceiving a sugar cube may evoke a precision grasp. Therefore, in multi-object situations where both objects are on the table, it is possible that the affordances evoked by each individual object, power and precision grasps, interfere with one another.

Yet most evidence in favor of object affordances is derived from single-object perception, which is relatively distant from naturalistic perceptual situations. Moreover, recent studies have questioned the role of affordance evocation in the processing of visual objects and suggest that the evocation of grasp affordances from visual objects may only facilitate compatible motor responses in limited, action-relevant, situations (Bub et al., 2021; Heurley et al., 2020). Many prior studies in this area of research have employed perceptual settings that are far removed from ecological conditions, using single-object stimuli presented with minimal visual context. Thus, while we can be fairly confident that in favorable situations, manipulable objects can evoke affordances, the consequences of affordance evocation on object perceptual processing in more naturalistic situations remain to be determined. In particular, as objects are rarely perceived in isolation, the impact of the evocation of multiple affordances on object perceptual processing is still uncertain. Returning to our initial example, the visual scene of a breakfast table encompasses numerous objects that may elicit multiple affordances. Then the question arises regarding whether and how these multiple affordances will influence the perceptual processing of the glass on the table.

A first line of research has investigated the influence of the evocation of multiple affordances on object processing by comparing action planning and perceptual judgements on single objects evoking distinct affordances in grasp-to-move and grasp-to-use contexts ("conflictual" objects, e.g., kitchen timer that may evoke a power grasp in a move context and precision grasp in a use context) and objects evoking similar affordances ("non-conflictual" objects, e.g., glass evoking power grasp in both move and use contexts). Findings highlighted a behavioral cost for conflictual objects in comparison to non-conflictual objects (Jax & Buxbaum, 2010; Kalénine et al., 2016). In a first study, Jax and Buxbaum (2010) asked participants to perform reach-and-grasp actions toward conflictual and non-conflictual objects. Results showed slower initiation times for grasp actions toward conflictual than non-conflictual objects. Similar results were obtained when participants had to perform perceptual judgements on the objects (Kalénine et al., 2016). The neural processes underlying this behavioral cost were further investigated in neurophysiological studies. Wamain et al. (2018) examined the differences in Mu desynchronization, a sensory-motor rhythm reflecting the activity of the motor system, when perceiving conflictual and non-conflictual objects. Results showed that the perception of conflictual objects led to a suppression of Mu rhythm desynchronization observed for non-conflictual objects. Overall, findings are consistent with the affordance competition hypothesis (Cisek, 2007). When dissimilar affordances are evoked from a visual object, they will compete with each other, reducing the motor resonance induced by the perception of manipulable objects and slowing down object processing.

In parallel to this line of research, a few authors focused on the evocation of several affordances from multiple visual stimuli, involving meaningless or familiar graspable objects (Ellis et al., 2007; Haddad et al., 2023; Pavese & Buxbaum, 2002). In a recent study, Haddad et al. (2023) presented pairs of two handled objects composed of one kitchen utensil and one tool, one on the left and one on the right. In addition, each object of the pair was oriented for a left- or right-hand grasp so that the two objects of the pair evoked similar or dissimilar affordances in terms of hand effectors. Participants had to identify the target object from the distractor (tool or utensil, task counterbalanced between participants) by performing left or right key presses, compatible or incompatible with the left/right hand affordance evoked by the target. When participants selected a compatible target with their dominant hand, results showed a cost for similar affordances, with slower target identification when target and distractor evoked similar left/right hand affordances in comparison to dissimilar affordances. Overall, the results highlight an interference in the opposite direction of the competition cost found for multiple affordances evoked by a single object. While a competition cost is observed for the processing of conflictual objects evoking *dissimilar* affordances in single-object situations (Jax & Buxbaum, 2010; Kalénine et al., 2016), a cost is observed for selecting a target object with *similar* affordances to the distractors in multi-object situations (Haddad et al., 2023).

A model has been proposed to explain the interference from distractors with *similar* affordances on target object processing (Vainio et al., 2011, 2014; Vainio & Ellis, 2020). The effect relies on a mechanism based on inhibition of the distractor objects and their affordances. According to the "inhibition hypothesis", when multiple objects are presented, distractor objects and their affordances are automatically inhibited to interact properly with the target object. When target and distractor evoke similar affordances, the affordance of the target will also be inhibited as it is similar to the distractor affordance, thereby slowing down target processing ("similarly to negative priming"; see Vainio & Ellis, 2020). However, very few studies support the inhibition hypothesis (Ellis et al., 2007; Haddad et al., 2023; Pavese & Buxbaum, 2002) and only one study involved multiple familiar objects (Haddad et al., 2023). Other studies involved stimuli conveying little meaning (e.g., cylinders and cubes; Ellis et al., 2007; single cup exemplar, Pavese & Buxbaum, 2002), which are known to induce lower motor resonance (Creem-Regehr & Lee, 2005). In addition to increasing motor resonance, the presentation of familiar objects should further impact affordance effects via the processing of object knowledge. The computational model proposed by Caligiore et al. (2010, 2013) evaluated the “inhibition hypothesis” by simulating the functioning of the dorsal and ventral neural pathways in the processing of objects with similar and dissimilar affordances. The model was able to reproduce the interference from distractors with similar affordances previously reported (Ellis et al., 2007). Importantly, it brings evidence for affordance similarity effects based on the joint involvement of the dorsal and ventral neural pathways involved in encoding of action information and processing of object knowledge, respectively (Buxbaum & Kalénine, 2010). This strongly suggests that object knowledge plays a role in affordance effects. In this view, object identity but also semantic relations between objects may therefore influence how affordances affect object processing in “naturalistic” perceptual situations involving several familiar objects.

When presenting multiple objects in a scene, objects are typically part of the same spatiotemporal context and thus often semantically related. For example, in a kitchen the objects present are utensils that can be used together, such as a knife and a cutting board. These specific relations between objects correspond to thematic relations, which are defined as objects that “perform complementary roles in the same scenario or event” (Estes et al., 2011, p. 251). Thematic relations are particularly relevant in the context of evoking affordances from multiple objects, as several studies demonstrated share common neural pathways and neurocognitive mechanisms with action (Kalénine, Peyrin, et al., 2009; Kalénine & Buxbaum, 2016; Mirman et al., 2017; Tsagkaridis et al., 2014). First, studies have shown that thematic relations are particularly salient for manipulable artefacts, in comparison to other object categories or other types of semantic relations (Kalénine, Bonthoux, et al., 2009; Kalénine & Bonthoux, 2008; Pluciennicka et al., 2016). Furthermore, identification of thematic relations involves selective activation of temporal and parietal brain regions (i.e., inferior parietal lobule, posterior middle temporal gyri, middle frontal gyrus and precuneus), which also support an important overlap in the brain regions underlying processing of action and thematic relations (Canessa et al., 2008; Kalénine, Peyrin, et al., 2009). Moreover, the left posterior temporal cortex has been found critical for both the identification of thematic relations for artefact objects and the recognition of object use gestures in participants with lesions of the left hemisphere after stroke (Kalénine & Buxbaum, 2016). Overall, results suggest that gesture recognition and thematic relations for artefacts both depend on some kind of manipulation knowledge.

Regarding the processing of thematic relations, studies have shown that thematically related objects presented in action-relevant thematic pairs are processed faster than unrelated objects in patients suffering from visual extinction following posterior parietal damage (Riddoch et al., 2003, 2006), but also healthy individuals (Roberts & Humphreys, 2011; Roux-Sibilon et al., 2018; Yoon et al., 2010). In one study, Roux-Sibilon et al. (2018) presented participants with pairs of objects that were thematically related or unrelated. The objects were positioned for action (i.e., the active object of the pair located for a dominant right-hand grasp and the passive object located for a left-hand grasp) or in mirror-locations. Participants were asked to determine if the two objects of the pair were typically used together (action task) or typically found in a kitchen (decision task). An advantage of thematically related over unrelated pairs was highlighted, with faster response times for related than unrelated pairs when objects were correctly located for action and when the task was relevant for action. In this view, the perception and identification of multiple objects seems to be facilitated when the objects of a pair are thematically related, due to the strong action relation between the two objects. This facilitation may also rely on the representation of the use gesture of the active object tool in its context.

Several studies have demonstrated the role of context in the recruitment of use gesture representations during object conceptual processing (Kalénine et al., 2014; Wokke et al., 2016).

In particular, Wokke et al. (2016) showed participants tools and kitchen utensils on a screen, with participants set up in a kitchen and workshop environment (i.e., congruent or incongruent stimuli and contexts). Participants had to determine as fast as possible if the object presented was a target (instructed as kitchen utensils or tools) or a distractor by pressing keys. They were also required to withhold their response when a cross appeared. Results showed faster response times when objects were presented in a congruent in comparison to incongruent context. In addition, the analysis of brain activity during response withholding indicated a greater increase of N2 event-related potential for objects in congruent in comparison to incongruent contexts.

Overall, results suggest that presenting manipulable objects in their usual context of use facilitates their processing. From these neurophysiological and behavioral evidence, we hypothesized that when selecting an object among others, thematic relations between objects could reduce the interference entailed by the evocation of multiple affordances from the different objects of a scene, as thematically related objects may be jointly coded in the perspective of tool use or coded as part of a common context of use.

The present study has two main aims. First, we sought to test the model of Vainio and Ellis (2020) by investigating the effect of multiple affordances on perceptual processing of a target object when pairs of familiar manipulable objects evoking different grasp size affordances are presented. We aimed to examine the predictions of the inhibition hypothesis, which assume interference from distractors with *similar* affordances. Secondly, we aimed to determine the influence of thematic relations on this interference, following evidence of significant overlap between thematic and action processing (Canessa et al., 2008; Kalénine, Peyrin, et al., 2009; Kalénine & Buxbaum, 2016; Mirman et al., 2017; Tsagkaridis et al., 2014) and critical interactions between dorsal and ventral neural pathways during object selection for action (Binkofski & Buxbaum, 2013; Buxbaum & Kalénine, 2010; Caligiore et al., 2010, 2013; Cisek, 2007).

To investigate these effects, we presented three dimensional (3D) scenes involving pairs of familiar objects on a table. One object was the target, the other one the distractor. Objects evoked grasp size affordances (i.e., power or precision grasps), with the target and distractor evoking similar affordances (e.g., both objects evoking a power grasp) or dissimilar affordances (e.g., target evoking power grasp and distractor evoking precision grasp). Additionally, the pairs of objects presented could be thematically related (e.g., a spatula and a pan) or unrelated (a spatula and a snow globe). Participants performed color judgments on the target object by executing power and precision grasp responses compatible or incompatible with the grasp evoked by the target object. This stimulus-response compatibility paradigm assessed affordance evocation during perceptual processing of objects. Although participants had to plan a manual action on the device, they did not have to directly reach and grasp for the objects, but rather had to judge their perceptual properties. Based on the inhibition hypothesis and previous findings with left/right hand affordances (Haddad et al., 2023), we predicted slower processing of the target object when distractors with similar grasp size affordances were present, compared to when distractors with dissimilar affordances were present. Furthermore, we hypothesized that the thematic relations between objects would facilitate the processing of the two objects as single affordance and reduce the interference from distractors with similar affordances during target selection. In other words, the interference from distractors with similar affordances would be particularly salient when target and distractor objects are unrelated. The interference should be reduced (or eliminated) when objects are thematically related.

2- METHOD

2.1- Population

Sixty-five young adults (51 females) between 18 and 40 years old (*M* = 20.80; *SD* = 2.21) were recruited. Only right-handed participants were selected, as visual stimuli were presented so that they would evoke right-hand actions. Handedness was verified according to the Oldfield Edinburgh test (participants with a laterality index superior to 50 were considered right-handed; Oldfield, 1971). All participants reported normal or corrected-to-normal vision. The stimuli being exemplars of meaningful objects, we had to make sure that participants were familiar with them. As the familiarity with objects is culturally driven, we recruited only French or living in France participants. The recruitment took place in 2022 on the campus of the University of Lille, where students were recruited. The study was conducted in accordance with the Helsinki declaration of 1964 and approved by the Ethical Committee of the University of Lille (reference 2021-536-S98). Participating in the study allowed students in Psychology to earn course credits.

2.2- Justification of the number of participants

Simulation-based power analysis was used to estimate sample size, following the guidelines presented in Kumle et al. (2021) using the function R2power of the package mixedpower (v0.1.0;Kumle et al., 2021) on R 4.1.2 software (R Core Team, 2021). We based our simulations on a preliminary dataset obtained from 35 participants. We aimed to determine the number of participants and the number of trials per condition that would be sufficient to detect an interaction between the similarity of affordances, thematic relations and compatibility between target and response, if it exists. Results of the simulation procedure (1000 simulations) for different sample sizes in terms of participants and items showed that 65 participants allowed to detect an effect with a power of .81.

2.3- Stimuli

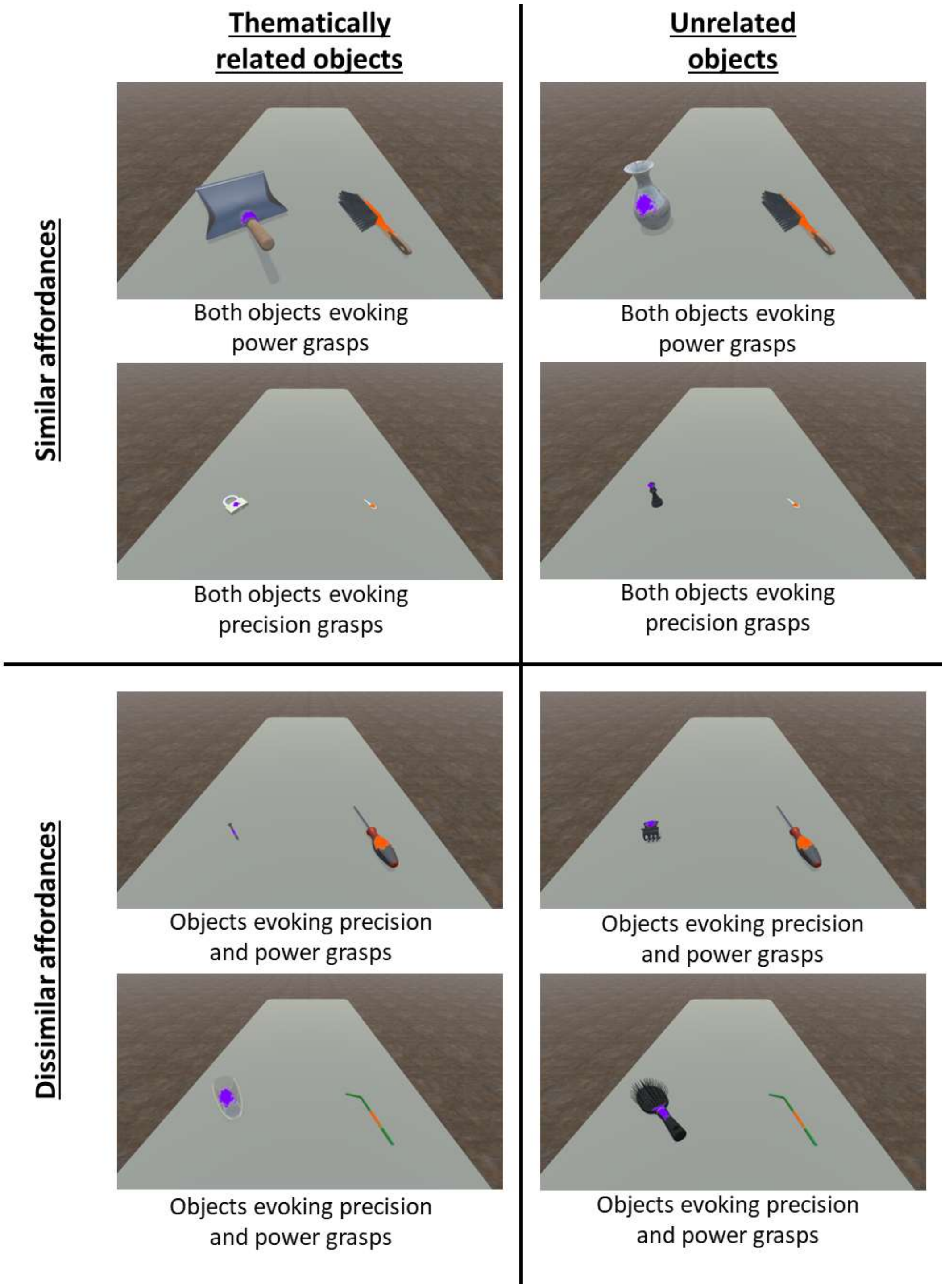
Stimuli were 532 images of scenes of two objects generated using Unity Software. The scenes were presented in 3D in order to increase the recognition and multisensory processing of objects and maximize the perception of affordances (Snow & Culham, 2021). Objects were manipulable (e.g., graspable with a single hand) and selected to be associated with only one possible grasp, namely a power grasp (clench;) or a precision grasp (pinch). For instance, for a hammer, the same power grasp may be used both to grasp it and to use it. Twenty reference objects were considered. For each object of reference (e.g., a spatula), two distractor objects were selected: a thematically related distractor (e.g., a pan) and an unrelated distractor (e.g., a snow globe), forming 20 sets of three objects (the list of sets of three objects can be found in Appendix 1). Objects were presented in pairs, for a total of 60 pairs of objects (20 items with 3 different presentation combinations) including a reference object and a thematically related distractor (e.g., the spatula with the pan), a reference object with an unrelated distractor (e.g., the spatula with the snow globe) and a thematically related distractor with an unrelated distractor (e.g., the pan with the snow globe). In the 20 sets of objects, 10 sets were composed of the reference object and the distractor object evoking similar grasp size affordances with 5 sets with two clenchable objects and 5 sets with two pinchable objects. The remaining 10 sets corresponded to the reference object and distractor object evoking dissimilar affordances with 5 sets where the reference object was clenchable and the distractor was pinchable, and conversely for the other 5 sets.

Objects of a pair were displayed on a table and were symmetrically disposed at equal distance from the center of the screen, one object on the left and one on the right. All objects were oriented for a right-hand action (e.g., the handle of a pan was oriented toward the right). A color stain, orange or purple, was displayed on each object, with the two objects of the pair having a different color stain. Each set was presented in 12 different combinations: each pair of objects was presented in four different displays, each object occupying the left or right location of the scene and appearing with an orange or a purple stain, for a total of 20 sets * 3 pairs * 4 combinations = 240 images. In addition, 40 catch images were introduced (see procedure).

Those images corresponded to one object of each set presented with an hourglass. Twelve additional images served as training.

Figure 1

Example of the different stimulus conditions.



Note. Pairs of objects could be thematically related or unrelated. Both objects of the pair could evoke similar affordances (both objects were clenchable or pinchable) or dissimilar affordances (one clenchable object and one pinchable object). Objects appeared in 3D in the experiment.

2.4- Response device

During the task, participants were asked to perform different grasps on a device created for this study (see Figure 2). The response device is divided into two distinct parts: a horizontal base covered with one sensor and a monotonic vertical cylinder with two sensors, one on the inferior half and one on the superior half. The sensors are touch sensors that are able to detect presses and releases of the device. First, participants positioned their index on the base of the device as an initial position. They responded to the task (i.e., determining the color of the stain on the target object; see the *Procedure* section for further details about the task) by releasing the initial position and performing grasp responses on the vertical cylinder. They performed either a power grasp (i.e., grasping with the whole hand the entire cylinder- clench) or a precision grasp (i.e., grasping with the thumb and index finger the superior half of the cylinder - pinch). Power grasps corresponded to two simultaneous presses on both the superior and inferior sensors of the cylinder. Precision grasps corresponded to a single press of the superior sensor of the cylinder. Release from the horizontal base was considered as movement initiation.

2.5- Procedure

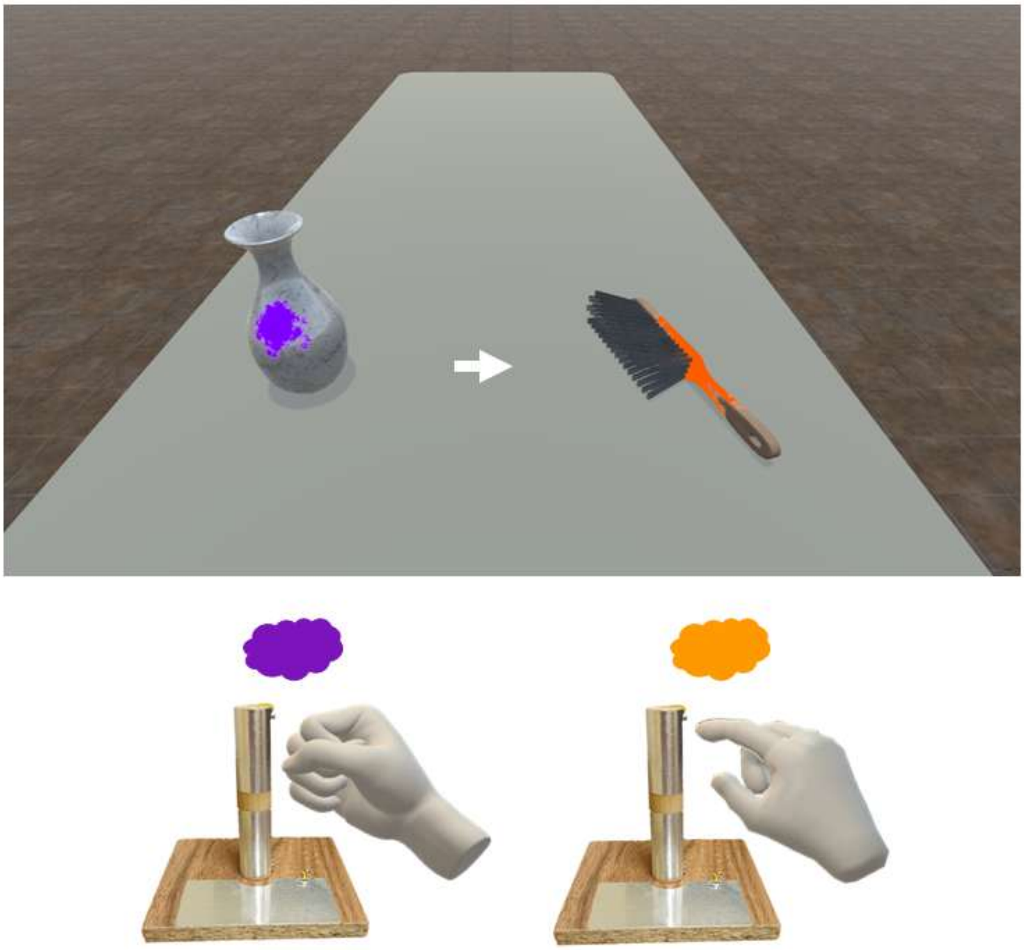
A letter was sent to the participants several days before the testing, to inform them about the aim of the study, the risks and benefits of their participation and their rights as participants. The letter was reviewed a second time with the participant on the testing day. After reviewing the letter, the informed consent of participants was collected. A random anonymous code (ascending number) was then attributed to each participant. The handedness of the participants was assessed with the Oldfield questionnaire (Oldfield, 1971) before familiarizing participants with the object stimuli to be used in the experiment. This procedure was done to make sure that there would be no possible doubt about the identification of each object before starting the actual experiment. Two dimensional versions of the objects were presented one at a time with their names written underneath and participants reviewed each object individually. After this familiarization phase, the experiment started. The experiment was built with MATLAB (MathWorks, Natick, USA) using Psychtoolbox. The images were presented on an LCD screen (1920x1080 pixels, 120Hz). Active 3D glasses were used to present the images in 3D (NVIDIA 3D vision 2, P1431). Two image versions of the same stimulus were designed and presented alternatively for each eye during 8.33 ms (e.g.,Kalénine et al., 2016). Participants were able to perceive a single image 3D as the visual system naturally fused the two images into one with this set-up.

In the experiment, participants had to perform a color judgment: they had to determine the color of the stain on the target object cued by an arrow (Figure 2). While not specifically relevant for action, this task allowed keeping our factors of interest (i.e., similarity between affordances and compatibility between target and response) within-subject. In addition, when catch trials were presented (i.e., when one of the objects of the scene was an hourglass), participants were asked to refrain from responding and stay in the initial position. Those catch trials were added to the experiment to ensure participants paid equal attention to each object of the scene. Each trial (Figure 3) began with the display of an empty table with instructions to get into the initial position. Once in the initial position, the instructions disappeared, and a fixation cross appeared for 500 ms. The scene of two objects was then displayed for a random duration of 400 ms, 600 ms or 800 ms. Next, an arrow appeared on the scene, pointing toward the target object for 3000 ms. Participants had to determine the color of the object pointed by the arrow by performing a right grasp on the device as fast and accurately as possible and by staying into the grasp position until the end of the trial. Half of the participants were instructed to perform a power grasp when the target object had an orange stain and a precision grasp when the target object had a purple stain and conversely for the other half of participants. After 3000 ms, the next trial started, with participants returning to the initial position. The experiment consisted of

480 trials (plus 40 additional catch trials and 12 practice trials) with the two pinchable or two clenchable (similar affordances) or one pinchable object and one clenchable object (dissimilar affordances). The affordance evoked by the target object could also be compatible with the response grasp (e.g., clenchable target and power grasp response) or incompatible (e.g., pinchable target and precision grasp response). Finally, the objects of the pair could be thematically related or unrelated. Participants were proposed a break halfway through the experiment and they were debriefed at the end. The total duration of the experiment was 45 minutes.

Figure 2

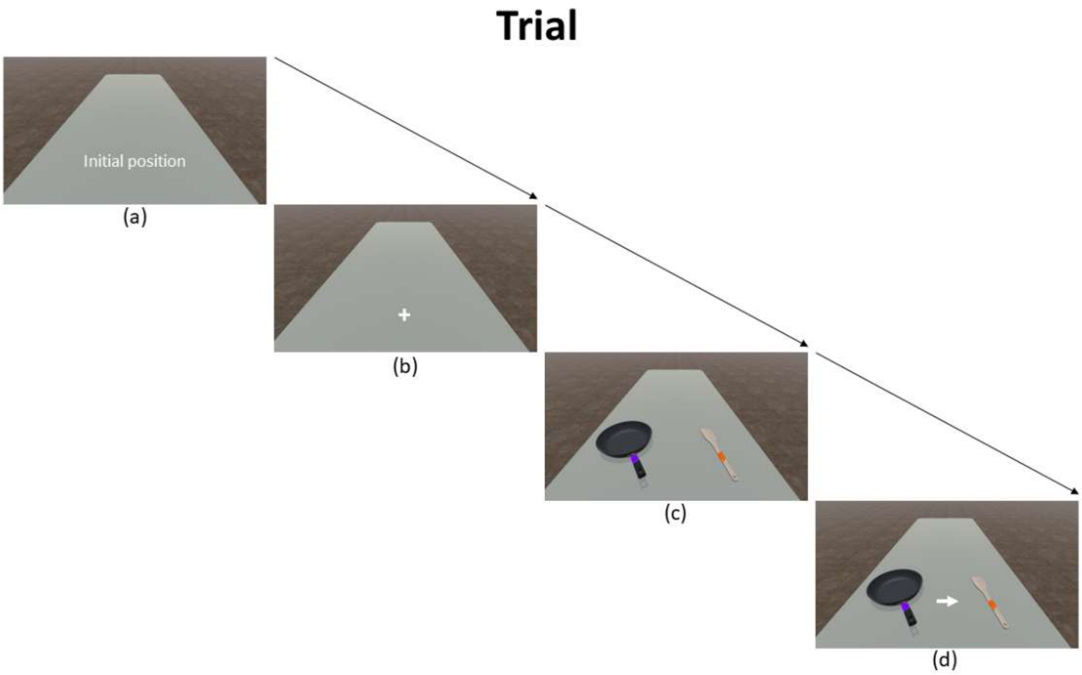
Illustration of the task.



Note. An arrow appeared on the scene and pointed toward an object which became the target. Participants had to perform a color judgment: they had to determine the color of the stain on the target object cued by the arrow. On the response device, the horizontal base served as the initial position of the movement. Participants had to place their index finger on the horizontal base before performing grasp responses: a power grasp using the whole hand on the entire cylinder or a precision grasp using the thumb and index fingers on the superior half of the cylinder.

Figure 3

Schematic representation of a trial.



Note. (a) Instruction to get into initial position. (b) A fixation cross appeared for 500 ms. (c) The two objects appeared on the scene for a duration of 400 ms, 600 ms or 800 ms. (d) An arrow appeared and pointed toward the target object, participants had 3000 ms to determine as fast and accurately as possible the color of the stain on the target object before moving to the next trial.

2.6 - Transparency and openness

Stimuli, raw data and analysis codes are available at https://doi.org/10.5281/zenodo.10447263. Simulation-based power analysis was used, following the guidelines of Kumle et al. (2021) and using the function R2 power of the package mixedpower (v0.1.0;Kumle et al., 2021) on R 4.1.2 software (R Core Team, 2021). Data pre-processing was conducted on R 4.1.2 software (R Core Team, 2021) using the packages plyr (v1.8.6;Wickham, 2011) and tidyverse (v1.3.1;Wickham et al., 2019). Data analyses were conducted using the packages lme4 (v1.1-27.1; Bates et al., 2015), emmeans (v1.7.2; Lenth et al., 2018) and lmerTest (v3.1-3; Kuznetsova et al., 2017). This study's design and the analyses were not pre-registered.

3- RESULTS

3.1- Data preprocessing

We first checked the score of handedness of each participant on the Oldfield questionnaire (Oldfield, 1971) and excluded five left-handed participants (corresponding to participants with a handedness score below 50). We then computed accuracy, considering true errors as an incorrect response grasp (a power grasp made instead of a precision grasp, a precision grasp made instead of a power grasp). We also considered errors grasps composed of two presses on the inferior and superior part of the device separated from more than 100 ms (100 ms is considered a minimum for a simple reaction time, Woods et al., 2015). As accuracy was at ceiling for true errors (M = 0.96, SD = 0.19) as well as when adding errors of non-simultaneous presses (M = 0.93, SD = 0.15), we did not further analyze it. We then checked responses on catch trials. As participants were asked to refrain from responding on those trials to ensure they paid equal attention to the two objects, we choose to exclude participants who answer incorrectly to more than 30% of those trials (incorrect answer to more than 12 catch trials out of 40). At this step, four participants were excluded. For the remaining pre-processing, only correct reference trials (when the target object was the reference object) were kept, and two different times were considered: i) Initiation Times (ITs) corresponding to the latency between the stimulus presentation and the release of the initial position and ii) Movement Times (MTs) corresponding to the latency between the release of the initial position and the grasp response. We expected to find an effect of affordances on ITs as it was previously reported in the literature (Jax & Buxbaum, 2010; Smith & Pepping, 2010), due to the evocation of grasp affordances that would be reflected on the planning phase of the grasp action. However, we also analyzed MTs, as it has been suggested that affordances may also be reflected in the action itself and not only its planning (Smith & Pepping, 2010). Analyzing both ITs and MTs also allowed to capture different response strategies that would be reflected at a different phase of the grasping action. We conducted the remaining preprocesses on the reference trials, where the target object was the reference object of the pair presented with either its thematically related associate or the unrelated associate. On these correct reference trials, we first applied a global trim on ITs and global response times (RTs, sum of Its and MTs), excluding trials in which RTs exceeded 2500 ms and ITs shorter than 100 ms, with 2.53% of trials excluded. A second trim per subject and condition was conducted on ITs and MTs. Trials were trimmed at more than 2.5 SD from the individual mean, which excluded 1.84 % of trials for a total of 4.37% of trials removed after the trimming procedure. We finally checked for outliers on accuracy and RTs. We considered outliers participants who performed at chance level (here 53%, following the binomial law, with 480 trials and a probability of success of 0.5) or participants with individual mean RTs at more than 2.5 SD from the mean RTs of the whole sample. No outlier participants were found. The following analyses were then conducted on correct trimmed trials of 56 participants.

*3.2-E*xplicit judgements of semantic relatedness and object-related grasps

Stimuli were rated on semantic relatedness and associated grasps in three separate samples of 20 right-handed participants who did not participate in the study. Ratings are provided in Appendix 3. In the first sample, participants were presented with 2D versions of the 60 object pairs with their names and had to judge to what extent the two objects of each pair were related on a Likert-type scale between 1 (not related at all) to 5 (highly related). For each critical object pair, we computed the median rating of participants. Related pairs were all judged highly related (median rating of 4 or 5 for all items) and unrelated pairs were all judged poorly related (median 1 or 2 for all items). A Wilcoxon test comparing median judgments for related and unrelated pairs further showed that related pairs were judged significantly more related (median = 5) than unrelated pairs (median = 1, W = 210, p < .001). In the second sample, participants were presented with 2D versions of each object and two hand postures of choice (power grip, precision grip). They had to choose the hand posture that best corresponded to how they would grasp the object. The number or power grasp and precision grasp responses was computed for each object. All 20 objects except two (i.e. ink and nail polish) received a majority of responses compatible with the grasp anticipated. These two items were excluded from further analysis. Finally in the third sample, participants were presented with 2D versions of the 60 object pairs and had to judge to what extent the two objects of each pair were graspable with a similar grasp on a Likert-type scale between 1 (grasps not similar at all) to 5 (grasps highly similar). For each critical object pair, we computed the median rating of participants. A Wilcoxon test comparing global median judgments for related pairs evoking similar and dissimilar grasps showed that related similar pairs were judged significantly more similar (median = 3) than related dissimilar pairs (median = 1, W = 95, $p < .001$). Similarly, unrelated similar pairs were judged significantly more similar (median = 3) than unrelated dissimilar pairs (median = 1, W = 100, $p < .001$). Importantly, similar related pairs (median = 3) were equivalent to similar unrelated pairs (median = 3, W = 59, $p = .503$) and dissimilar related pairs (median = 1) were equivalent to dissimilar unrelated pairs (median = 1, W = 52, $p = .871$). At the item level, all critical pairs except two (credit card-wallet, USB cable – hard drive) were judged similar or dissimilar as anticipated. These two items were excluded from further analysis. The final sample for the analysis of affordance similarity effects in the main task included 16 of the 20 item sets.

3.3- Main analyses

Linear mixed-effect models were conducted on ITs and MTs, after the conditions for using linear models were verified with residual distribution inspection and skewness tests. Fixed effects were Compatibility between stimulus and response (compatible, incompatible), Similarity between affordances (similar, dissimilar) and thematic Relations between objects (related, unrelated) as within-subject factors. Random structures corresponded to the maximum random structures of the models supported by the data, following the procedures proposed by Barr et al. (2013) and Bates et al. (2015). We considered intercepts and slopes for the random effects of participants and items when possible. When the models did not converge, we reduced the random structures by running Principal Component Analyses to estimate the part of variance of our model explained by each intercept and slope with the rePCA function from the lme4 package (v1.1-27.1; Bates et al., 2015). We chose to keep the intercepts and slopes that explained the biggest part of variance. We removed the ones that explained the least variance, repeating this process until the models converged. The final mixed model structures and R syntaxes can be found in Appendix 2. Effect sizes were computed as Wesftall's d, an alternative to Cohen's d suitable for linear mixed model effects (Brysbaert & Stevens, 2018; Westfall et al., 2014). Westfall's d measures were computed using the eff_size function of the emmeans package (v1.7.2;Lenth et al., 2018). We expected an interaction between Compatibility, Similarity and Relations, which would reflect the fact that the processing of a compatible target is influenced by both the similarity of the target-distractor affordances and the presence of thematic relations between the pair. In line with the inhibition hypothesis (Caligiore et al., 2010, 2013; Vainio & Ellis, 2020) and previous findings (Haddad et al., 2023), we specifically expected an interference from distractors with similar affordances on target judgements with longer ITs to target objects in the presence of distractors with similar affordances, compared to dissimilar affordances. Furthermore, interference from distractors with similar affordances should be reduced when target and distractor also share a thematic relation. The impact of distractor objects (affordance similarity and thematic relations) on target processing should be visible in compatible situations, when the response grasp performed is relevant to act on the target object. Therefore, after verifying the 3-way interaction between Compatibility, Similarity and Relations, four comparisons of interest were considered a priori. We directly contrasted target responses in presence of similar and dissimilar distractors in each of the four conditions (compatible responses and unrelated distractors, compatible responses and thematically related distractors, incompatible responses and unrelated distractors, incompatible responses and thematically related distractors).

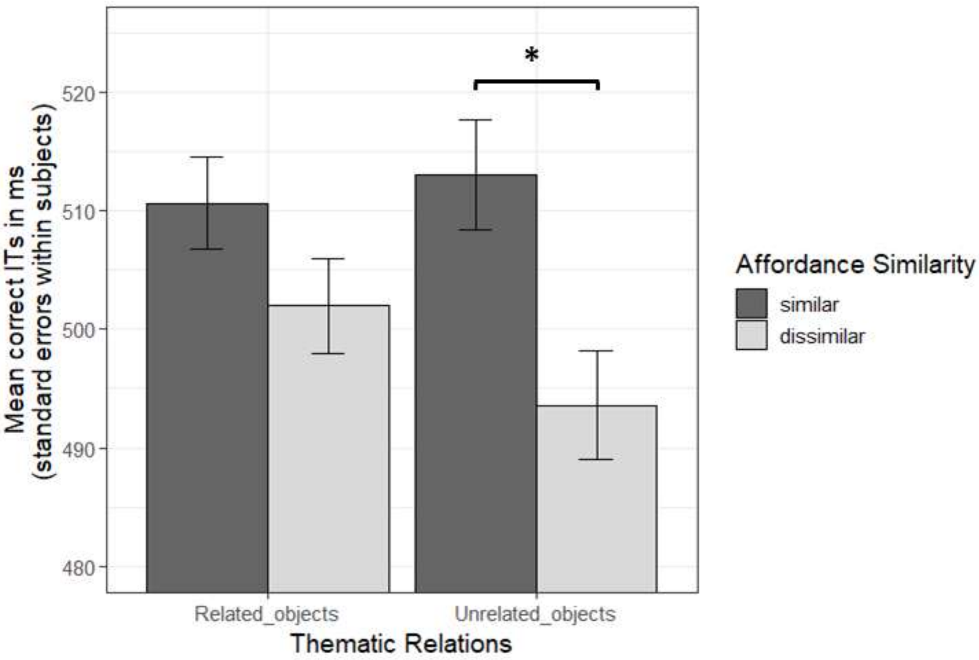
3.3.1- Initiation Times

Table 1 presents the means and standard deviations of initiation times (IT) in the different conditions. The three-way interaction of interest between Compatibility, Similarity and Relations was significant (estimate = 9.282, t = 2.240, SE = 4.144, p = .025, Westfall's d = .058). Paired comparisons evaluating a priori contrasts of interest showed the expected effect of affordance similarity: for unrelated objects, distractors with similar affordances interfered with the processing of compatible targets, with longer ITs for distractors with similar (M = 513, SD = 106) than dissimilar (M = 493, SD = 99) affordances (estimate = 18.725, z = 2.473, SE = 7.570, p = .013, Westfall's d = .103). For related objects, there was no interference from distractors with similar affordances on the processing of compatible targets: the difference of ITs between distractors with similar (M = 510, SD = 100) and dissimilar (M = 501, SD = 102) affordances was not significant (estimate = 9.049, z = 1.194, SE = 7.580, p = .232, Westfall's d = .057). This pattern is illustrated on Figure 4. It is important to note that the similarity of distractor affordances did not have a significant impact on the processing of incompatible targets for unrelated objects (estimate = -3.090, z = -0.407, SE = 7.600, p = .684, Westfall's d = .019) or related objects (estimate = 13.489, z = 1.774, SE = 7.600, p = .076, Westfall's d = .085) although qualitatively, related distractors would lead to slower responses to incompatible targets when similar compared to dissimilar. Finally, the main effects of Similarity (estimate = -6.748, t = -1.692, SE = 3.987, p = .108, Westfall's d = .042), Relations (estimate = -2.026, t =

-0.978, SE = 2.072, *p* = .328, Westfall's d = .012) and Compatibility (estimate = 3.754, *t* = 1.811, SE = 2.073, *p* = .070, Westfall's d = .023) were not significant.

Figure 4

Mean ITs for compatible trials as a function of Similarity and Relations.



Notes. * *p* <.05. Error bars correspond to the within-subject standard errors.

Table 1

Mean ITs (SD) in milliseconds as a function of Relations, Compatibility and Similarity.

Relations	Compatibility	Similarity	Mean (SD)
Related objects	Compatible	Similar	510.639 (100.627)
		Dissimilar	501.970 (102.866)
	Incompatible	Similar	518.769 (110.984)
		Dissimilar	503.804 (105.022)
Unrelated objects	Compatible	Similar	513.041 (106.933)
		Dissimilar	493.590 (99.945)
	Incompatible	Similar	506.883 (101.628)
		Dissimilar	510.156 (105.121)

3.3.2- Movement times

The three-way interaction between Compatibility, Similarity and Relations did not reach significance (estimate = 9.347, $t = 1.788$, SE = 5.229, $p = .073$, Westfall's d = .048). However, the interaction between Compatibility and Similarity was significant (estimate = 10.735, $t = 2.902$, SE = 3.699, $p < .01$, Westfall's d = .056). Paired comparisons between affordance similar and dissimilar conditions for compatible and incompatible targets showed that distractors with similar affordances interfered with the processing of compatible targets, with longer MTs for distractors with similar ($M = 511$, $SD = 100$) than dissimilar ($M = 497$, $SD = 98$) affordances (estimate = 19.225, $z = 2.654$, SE = 7.240, $p < .01$, Westfall's d = .100). Importantly, the similarity of distractor affordances had no impact on the processing of incompatible targets (estimate = -2.245, $z = -0.309$, SE = 7.270, $p = .757$, Westfall's d = .011). Regarding main effects, only the main effect of Compatibility was significant (estimate = 7.917, $t = 3.027$, SE = 2.616, $p < 0.01$, Westfall's d = 0.041) with faster MTs for compatible ($M = 505$, $SD = 98$) than incompatible target and response ($M = 510$, $SD = 102$). The main effects of Similarity (estimate = -6.003, $t = -1.360$, SE = 4.413, $p = .193$, Westfall's d = .031) and Relations (estimate

= -1.587, *t* = -0.617, SE = 2.615, *p* = .544, Westfall's d = .008) were not significant. The descriptive statistics of mean MTs and standard deviations for the Compatibility x Similarity x Relations conditions are provided in Appendix 4.

3.4- Complementary analyses

Complementary analyses were conducted to further explore the possible role of perceptual differences_in affordance similarity effects and quantify the impact of thematic relatedness of object selection more directly. They were performed on Initiation RTs and based on the results of the linear mixed models reported in the main analysis section.

3.4.1- Contribution of possible perceptual differences between objects

The stimulus pairs evoking similar and dissimilar affordances did not involve the same objects (e.g., key-lock evoking similar affordances and screwdriver-screw evoking dissimilar affordances). In addition, for a given set of objects, thematically related and unrelated pairs inherently involved the same reference object but a different distractor (e.g., screwdriver-screw or screwdriver-hair clip). One could then argue that the effect of affordance similarity observed may not be due to the evocation of multiple affordances but might be accounted for by visual differences between objects in the different conditions. Yet an important control lies in the incompatible condition, where objects were exactly the same as in the compatible condition, regardless of affordance similarity. The only difference was the response, which was incompatible with the grasp evoked by the target object. Compatibility effects (i.e., difference between response times in the compatible and incompatible conditions) thus reflect how strongly the target object affords the grasping action in the visual context it is presented. We assumed that the inhibition of the distractor object would also inhibit the evocation of its affordance. When the affordances of the distractor and the target are similar, the evocation of the same affordance from the target would be more difficult, and the compatibility effect should be reduced. Thus, if the effect of affordance similarity arises from the evocation of affordances, compatibility should be particularly visible when target objects are presented with unrelated dissimilar distractors. We ran post-hoc paired comparisons between compatible and incompatible conditions from the significant interaction between Compatibility, Similarity and Relations. The compatibility effect was only significant for unrelated objects evoking dissimilar affordances, with slower ITs in the incompatible (M = 510, SD = 105) than compatible (M = 493, SD = 99) condition (estimate = -16.254, z = -2.691, SE = 6.040, p < .01, Westfall's d = .103). Note however that this comparison did not survive Tuckey correction for post-hoc tests (p = .125). There were no significant differences between compatible and incompatible condition for unrelated objects evoking similar affordances (estimate = 5.560, z = 0.980, SE = 5.670, p = .326, Westfall's d = .035) or related objects evoking dissimilar (estimate = -3.053, z = -0.505, SE = 6.040, p = .613, Westfall's d = .019) or similar (estimate = -7.492, z = -1.318, SE = 5.680, p = .187, Westfall's d = .047) affordances. Compatibility effects are plotted as a function of Similarity and Relations in Figure 5.

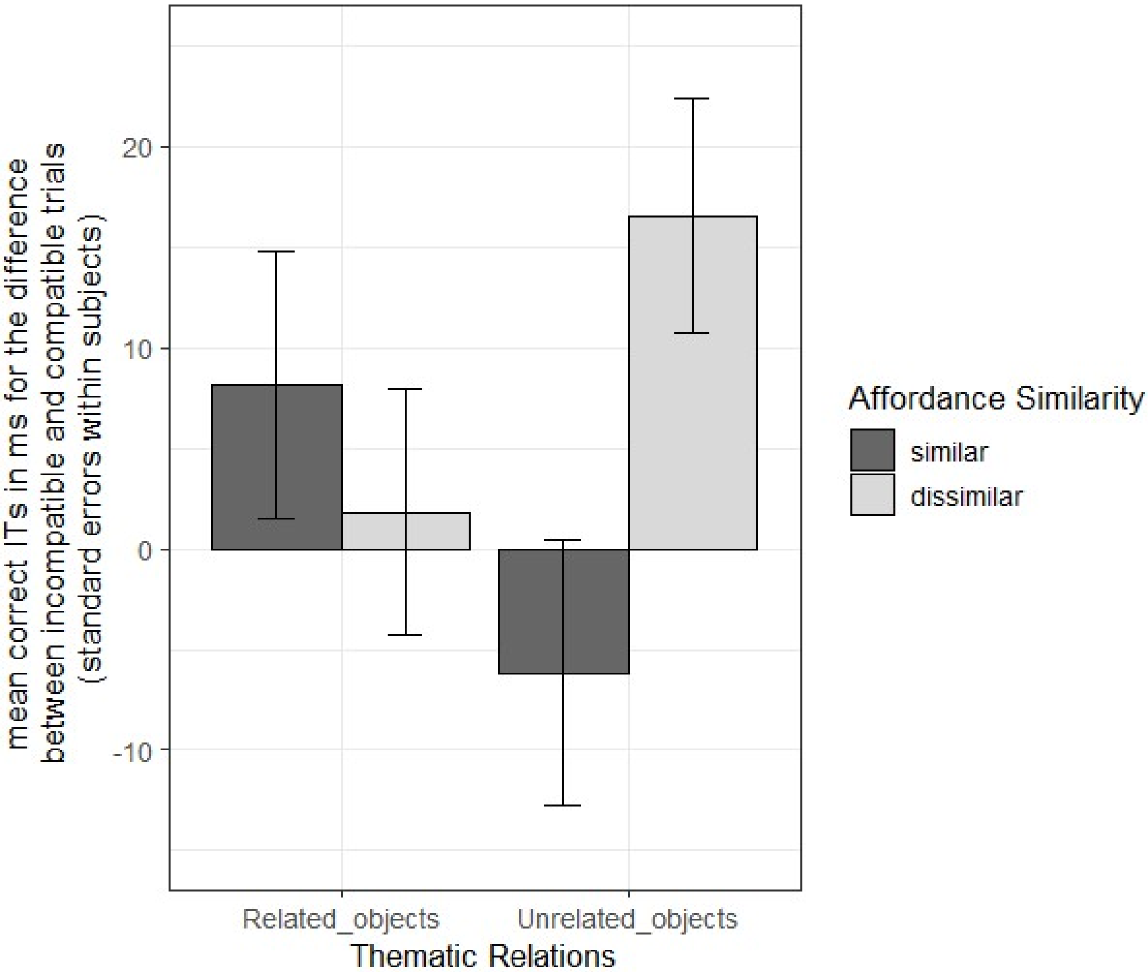
Additional comparisons rule out possible interpretations of the effect of affordance similarity on target processing in terms of perceptual differences between visual displays of objects with similar versus dissimilar affordances. Compatibility effects were only observed in the context of unrelated distractors with dissimilar affordances.

3.4.2 – Impact of thematic relatedness on target selection

If the presence of thematic relations prevents inhibition of the distractor affordance, one may expect faster response times to compatible targets when distractors with *similar* affordances are also thematically related, in comparison to unrelated. Conversely, one may expect slower responses to compatible targets when distractors with *dissimilar* affordances are also thematically related, in comparison to unrelated. Yet post-hoc paired comparisons between thematic and unrelated conditions from the significant interaction between Compatibility, Similarity and Relations did not show any significant difference. ITs to compatible targets were equivalent for thematic and unrelated pairs when objects evoked similar affordances (estimate = -1.934, z = -0.341, SE = 5.68, p = .733, Westfall's d = .012) as well as when objects evoked dissimilar affordances (estimate = 7.741, z = 1.288, SE = 6.01, p = .198, Westfall's d = .049). This suggests that inhibition of the distractor and its affordance leads to both interference (when affordances are dissimilar) and facilitation (when affordances are similar). The contribution of interference and facilitation to affordance similarity effects may be reflected in differences between conditions of similar and dissimilar affordances but may be not detected in the direct comparison between related and unrelated pairs in each affordance condition separately.

Figure 5

Compatibility effects (mean ITs for the difference between incompatible and compatible trials) as a function of Similarity and Relations.



Notes. Error bars correspond to within-subject standard errors.

4- DISCUSSION

This study aimed to investigate the influence of the evocation of multiple affordances on object processing. Previous studies have demonstrated that the evocation of dissimilar affordances from a single visual object leads to competition and slows down object processing. However, there is limited research on how the evocation of multiple affordances from different objects may affect object processing. Therefore, this research sought to examine whether affordances evoked by the different objects of a visual scene compete with one another and interfere with the selection of a target object in the scene. In addition, the study aimed to evaluate whether the presence of thematic relations between objects could modulate this interference phenomenon.

We specifically tested the predictions of the inhibition hypothesis proposed by Caligiore et al. (2010, 2013) and Vainio and Ellis (2020). According to this hypothesis, object selection involves inhibiting distractor objects and their affordances. In this perspective, the presence of distractor objects evoking affordances *similar* to the target object was expected to interfere more with target processing compared to the presence of distractor objects evoking *dissimilar* affordances. Interference from distractors with similar affordances was anticipated when the response grasp was compatible with the affordance evoked by the target object, namely when the response performed was relevant to act upon the target. Drawing upon the growing literature on action representations and thematic relations between objects, it was further hypothesized that the interference from distractors with similar affordances on target processing would be greatest for unrelated objects. When objects are thematically related, the two objects would be perceived as a unique action pair, which would limit the effect of distractor inhibition on target affordance evocation.

As expected, results showed that perceptual judgements on the target object were modulated by the similarity of affordances between target and distractor, the presence of thematic relations between target and distractor and the compatibility between the target and response grasps. When participants responded on the target object with a compatible grasp, initiation times were slower in the presence of unrelated distractors evoking similar compared to dissimilar affordances. Interference from distractor objects with similar affordances on target processing disappeared when target and response grasps were incompatible or when objects were thematically related. The direct comparison between the compatible and incompatible conditions confirmed that the selective interference observed for unrelated objects could not be explained by the use of different objects in the different scene conditions. Indeed, facilitative compatibility effects were only observed in the presence of unrelated distractors with dissimilar affordances.

Overall, our results aligned with the findings from the initial studies conducted by Ellis et al. (2007) and Pavese and Buxbaum (2002) on affordances and object selection. Importantly, we evidenced a significant influence of the affordances of distractor objects on perceptual processing of a target object with 3D naturalistic scenes featuring familiar objects. For the first time, we demonstrated interference from distractors with similar grasp size affordances using a large set of familiar and highly graspable objects. Findings support the predictions of the inhibition hypothesis of Caligiore et al. (2010, 2013) and Vainio and Ellis (2020). They suggest the involvement of a process of inhibition of distractor affordances associated with the selection of a target object. According to this interpretation, the visual presentation of the scene first evoked grasp affordances from the two objects. Then participants focused on the cued object of the pair to perform the color judgment and inhibited the affordance evoked by the distractor in order to select the relevant affordance for the task. When target and distractor evoked similar affordances, the relevant affordance was also inhibited, resulting in slower responses on the target.

One could argue that instead of inhibition, a competition mechanism between affordances of distractor and target objects may explain the pattern of results. Indeed, when target and response were compatible and when affordances evoked by target and distractor were similar, both affordances of target and distractor were compatible with the response grasp. From this perspective, it is possible that the compatibility of both objects with the grasp response leads to affordance competition when selecting the target. This competition (between objects, rather than between affordances) could then slow down target responses compared to situations where the affordances are dissimilar, and only the target affordance is compatible with the grasp response.

The second major contribution of our study is to provide evidence for an influence of thematic relations on the processing of objects evoking multiple affordances. The importance of semantic knowledge about objects in the processing of multiple affordances has been suggested by several plausible neural models (Binkofski & Buxbaum, 2013; Buxbaum & Kalénine, 2010; Caligiore et al., 2010, 2013; Cisek, 2007; Sakreida et al., 2016). These models stress the interrelations between stimulus processing in the dorsal and ventral visual pathways. While affordances may be specified along the dorsal pathway regardless of object identify (e.g., Almeida et al., 2014), information computed along the ventral stream may participate in affordance selection by biasing toward actions that are relevant for the current context, integrating information about object knowledge. In the present study, we brought novel evidence in favor of these models by demonstrating a key role of semantic thematic relations between objects in affordance selection from multiple objects.

Now the question is why do thematic relations reduce the cost of similar affordances during object processing? First, we may hypothesize that thematic relations between objects acted as contextual clues when processing scenes with objects, regardless of the specific action relation between thematically related objects. For example, when the two objects presented are a knife and a cutting board, the context of a kitchen may have been activated. This interpretation is based on previous work suggesting that the perception of objects in a scene is modulated by knowledge of co-occurring objects in a specific context (Lauer & Võ, 2022). In addition, Kalénine et al. (2014) and Wokke et al. (2016), highlighted a role of context in the representation of grasp gestures during visual object processing. Similarly, in our study, thematic relations between objects may activate a global context that facilitates the processing of the target object, thereby suppressing the interference caused by distractor objects with similar affordances.

In addition to the activation of a general congruent context, several other more specific mechanisms may also account for the elimination of the interference from distractors with similar affordances on target responses when objects are thematically related. One speculation is that the two affordances evoked by the target and distractor objects are perceived as one single affordance (instead of two distinct affordances) when objects are thematically related. This reasoning is supported by previous evidence of a paired-object affordance effect arising from thematically related objects (Riddoch et al., 2006; Roberts & Humphreys, 2011; Roux-Sibilon et al., 2018; Yoon et al., 2010). Paired-object affordances effects are reflected by faster response times to action tasks (i.e., determining if two objects are usually used together) when thematically related objects are presented located for action (e.g., a spatula located for a dominant right-hand grasp and a pan located for a left-hand grasp) than when thematically related objects are presented in mirror location (Yoon et al., 2010). In the present study, if participants perceived the two objects as a single affordance (i.e., a paired affordance), the distinction between similar and dissimilar distractor affordances would no longer be relevant and interference would not occur. However, unlike previous studies highlighting paired-object affordance effects, in our study objects were not correctly co-located for action but were always oriented for a right-hand grasp (e.g., objects with handles were oriented to the right). Therefore, it is unlikely that the specific effect observed for thematic relations relates to the paired-object affordance effect.

A second hypothesis at the inhibition level is that the affordances of related distractors are less inhibited than affordances of non-related distractors. When perceiving two thematically related objects, the affordance of the thematic associate may be more challenging to inhibit than the affordance of the unrelated associate due to the close action relations existing between thematically-related objects (Kalénine & Buxbaum, 2016; Mirman et al., 2017; Tsagkaridis et al., 2014). Reduced inhibition of the distractor affordance would help target responses when the target has a similar affordance and hinder target responses when the target has a dissimilar affordance, extinguishing affordance similarity effects.

Finally, it may also be possible that the affordances evoked by objects that are thematically related were perceived as a combined bimanual affordance and not two separate ones. As thematically related objects are typically manipulated simultaneously with both hands, it is possible that one object is perceived as compatible with a right-hand grasp and the other as compatible with a left-hand grasp. In this view, when objects are unrelated, the affordances evoked by the two objects compete against each other, as both affordances are compatible with a right-hand grasp. When objects are thematically related, the competition would disappear, as only one object affordance remains compatible for a right-hand. While the exact role of thematic relations between objects in affordance perception remains to be specified, the present study clearly demonstrates that it is critical to take into account these semantic relations when investigating perception-action interactions in multi-object situations.

We brought evidence of an effect of affordance similarity on judgements toward a target object and an influence of thematic relations between objects on affordance similarity effects. While the inhibition hypothesis predicts that target object selection will be impacted by the similarity of affordances, results from the present study do not ascertain that the effects obtained reflect a selection process. Participants were not directly instructed to select the target object and performed a color judgment task. Yet, results obtained in the present study are in line with results from the study of Haddad et al. (2023) where participants were specifically instructed to identify and select the target object (i.e., the kitchen utensil or the tool) from the other distractor object. In this view, it appears that the effect of similarity may be visible in different types of tasks, as long as participants have to process a target object and ignore a distractor object. In addition, as the response was performed after target cueing, it is not possible to determine if the effect appeared only after having to select an object from the other or if the effects already emerged from the perception of both objects. In other words, it is not possible at this stage to disentangle between object perception and object selection. Finally, the effect of affordance similarity may not be related to perceptual processing and selection of the target object but may reflect response selection (Castiello, 1996). In the present study, object perceptual judgements were confounded with the selection of response grasps. One may argue then that the effect of affordance similarity corresponds to an interference of response selection between two similar or dissimilar grasp responses. Further studies would be required to disentangle the role of object perception, object selection and response selection in the emergence of affordance similarity effects.

On another point, it is worth noticing that grasp affordance effects were evaluated with a stimulus-response compatibility paradigm. Although the interpretation of stimulus-response compatibility effects in the field of manipulable object perception has been largely debated, we believe that the pattern of results observed reflects the evocation of grasp size affordances from visual objects in the present study. It has been demonstrated that facilitation in compatible conditions between stimulus and response may at least partially arise from a match between abstract codes associated with the target (e.g., “large” object) and the response (e.g., “large” grasp; (Azaad et al., 2019; Cho & Proctor, 2010; Heurley et al., 2020; Proctor et al., 1990; Proctor & Miles, 2014). Yet studies have evidenced that in some specific action-relevant situations when task demands and response conditions are sufficiently relevant for action, the affordance of the objects can be evoked (Bub et al., 2018; Girardi et al., 2010). Importantly, the effect of affordance evocation and abstract coding may coexist in the stimulus-response compatibility paradigm. Pavese and Buxbaum (2002) were able to highlight two different influences of distractors on target selection, one drawn by the evocation of object affordances and one related to the match of stimulus and response visual properties. They reported an interference from distractors with *similar* affordances on target selection when the responses were relevant for action (i.e., for reach and grasp responses), which aligns with the evocation of affordances when perceiving distractor and target objects. However, when the responses were irrelevant for action (i.e., button press responses) they found an interference from distractors with *dissimilar* affordances on target selection. This is in line with the findings of Eriksen and Eriksen (1974), which showed that when distractors with dissimilar visual or abstract (i.e., not motor) properties to the target are associated with different responses, they interfere with target selection. Critically, our results demonstrate an interference from distractors with *similar* affordances on target selection only when target and response were compatible, namely when the grasp performed was relevant for the present action context. Therefore, we can be confident that in the present stimulus-response compatibility protocol, grasp size affordances were evoked from visual objects and contributed to the pattern of effects observed. Follow up studies may be beneficial to investigate, in a more direct manner, the respective contribution of abstract coding of stimulus and response properties and affordance evocation in compatibility effects. This could be done by contrasting compatibility effects for objects that may be coded as "large" but graspable with a precision grasp (e.g. a thin notebook) and small objects that may be coded as "small" but graspable with a power grasp (e.g. a highlighter), in order to determine if compatibility effects arise from an abstract coding of the object size or an evocation of its grasp affordance.

The present study has provided valuable insights into the impact of multiple affordances on object processing and the role of thematic relations between objects in modulating affordance effects. However, it is important to note that the study raised several considerations that warrant further investigation. First, novel results always need to be replicated and generalized to different items and populations. In the context of this particular study, considering diverse groups of participants (e.g., including non-college students, older adults) would be particularly relevant, as inhibitory mechanisms may vary as a function of several factors such as age or education. Second, additional research is required to test the involvement of an inhibition mechanism more directly, to address the necessity of manual responses in the emergence of affordance similarity effects, and to specify their temporal locus. Information about temporal dynamics would be highly valuable to determine whether the effect occurs at the stage of target and/or response selection. Electroencephalography (EEG) may be a relevant strategy to address these important remaining questions. For instance, analyses of μ rhythm desynchronization (see Wamain et al., 2018, 2023) would provide an index of activity of the motor system as a proxy for affordance evocation in the absence of manual responses. This would address the debate about the automaticity of affordance effects. In addition, EEG would allow to determine when the effects of affordance similarity and thematic relations appear by considering modulations of brain activity before and after target object cueing.

Finally, thematic relations between objects and similarity of affordances were manipulated in a very dichotomic manner in the present study (i.e., pairs of objects were either related or unrelated and affordances were either similar or dissimilar). Yet in naturalistic situations, the relations between objects and the similarity of affordances are probably much more continuous. One could imagine that the effects of affordance similarity and thematic relations between objects would be more gradual. For example, the stronger the relations between objects, the more they will affect the effect of affordance similarity.

5- CONCLUSIONS

We showed that the multiple affordances evoked by the different objects of a scene impacted object perceptual processing. Distractor objects with similar grasp size affordances interfered with target selection and slowed down target object processing. This interference appeared when participants performed response grasps compatible with the grasps evoked by the target object being processed. Importantly, interference from distractors with similar affordances was restricted to unrelated objects. Overall, the results are in line with the model of Caligiore et al. (2010, 2013) and Vainio and Ellis (2020) suggesting an inhibition process of the distractor affordances in order to select the relevant target affordance. In addition, thematic relations between objects facilitate the processing of similar affordances evoked by distractor and target objects. This facilitation may be due to the activation of a global congruent context but may also relate to the perception of paired-object affordance and/or to a greater difficulty to inhibit thematically-related distractors. Further investigations are needed to clarify how the interference from distractors with similar affordances on target processing is extinguished when objects are thematically related.

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APPENDIX 1: COMPLETE LIST OF STIMULI

Reference object	**Related distractor**	**Unrelated distractor**
Key	Lock	Chess piece
Feather	Ink	Domino
Nail polish brush	Nail polish	Eraser
Match	Candle	USB key
Clothespin	Sock	Ring
Straw	Glass	Hairbrush
Paint brush	Paint pallet	Bowl
Credit card	Wallet	Mug
Coin	Piggy bank	Vegetable peeler
USB cable	Hard drive	Rake
Toothpaste	Toothbrush	Blackboard eraser
Spatula	Pan	Snow globe
Brush	Dustpan	Vase
Knife	Cutting board	Hoe
Pitcher	Glass	Trowel
Hammer	Nail	Beer cap
Screwdriver	Screw	Hair clip
Racket	Ball	Safety pin
Cable clamp	Cable	Button
Wrench	Bolt	Document clip
Nut	*Nutcracker*	*Pen*

Examples appear in *Italic*.

APPENDIX 2: COMPLETE MIXED MODEL STRUCTURES AND R SYNTAXES

Initiation Times = Compatibility * Similarity * Relation

+ (1+ Similarity | Participants : Mapping)

+ (1+ | Items : Target Grasp : Distractor Grasp)

Movement Times = Compatibility * Similarity * Relation

+ (1 | Participants : Mapping)

+ (1 | Items : Target Grasp : Distractor Grasp)

APPENDIX 3: RATINGS FOR SEMANTIC RELATEDNESS AND OBJECT GRASPS

1) Ratings for semantic relatedness and affordance similarity

Pairs	Median Relation	Median Similarity
brush_dustpan	5	4.0
brush_vase	1	2.0
cableclamp_button	4	1.0
cableclamp_cable	1	1.0
card_mug	5	1.0
card_wallet	1	3.0
clothespin_ring	5	3.0
clothespin_sock	1	2.0
coin_bank	5	1.0
coin_peeler	1	1.0
feather_domino	5	3.0
feather_ink	1	2.0
hammer_beercap	5	1.0
hammer_nail	1	1.0
key_chesspiece	5	4.0
key_lock	1	3.0
knife_cuttingboard	5	3.5
knife_hoe	2	4.0
match_candle	5	3.0
match_USB	1	3.5
nailbrush_eraser	4	3.0
nailbrush_nailpolish	2	3.5
paintbrush_bowl	5	1.0
paintbrush_pallet	3	1.0
pitcher_glass	4	3.0
pitcher_trowel	1	2.0
racket_ball	5	1.0
racket_safetypin	1	1.0
screwdriver_hairclip	5	1.5
screwdriver_screw	1	1.0
spatula_pan	5	4.0
spatula_snowglobe	1	2.0
straw_glass	5	1.0
straw_hairbrush	1	1.5
toothpaste_boarderaser	5	2.0
toothpaste_toothbrush	1	3.0
USBcable_harddrive	5	2.0
USBcable_rake	1	1.0
wrench_bolt	5	1.0
wrench_documentclip	1	1.0

2) Ratings for objects associated grasps

Objects	Number of power grasp responses/20	Number of precision grasp responses/20
ball	7	13
bank	19	1
beercap	0	20
boarderaser	19	1
bolt	1	19
bowl	19	1
brush	19	1
button	0	20
cable	0	20
cableclamp	19	1
candle	3	17
card	2	18
chesspiece	0	20
clothespin	1	19
coin	0	20
cuttingboard	18	2
documentclip	1	19
domino	0	20
dustpan	19	1
eraser	1	19
feather	2	18
glass	19	1
glass2	18	2
hairbrush	19	1
hairclip	1	19
hammer	19	1
harddrive	13	7
hoe	19	1
ink	10	10
key	0	20
knife	16	4
lock	4	16
match	1	19
mug	18	2
nail	0	20
nailbrush	3	17
nailpolish	13	7
paintbrush	2	18
pallet	15	5
pan	18	2
peeler	17	3
pitcher	18	2

racket	19	1
rake	18	2
ring	0	20
safetypin	0	20
screw	0	20
screwdriver	17	3
snowglobe	18	2
sock	7	13
spatula	17	3
straw	1	19
toothbrush	11	9
toothpaste	11	9
trowel	18	2
USB	1	19
USBcable	4	16
vase	20	0
wallet	14	6
wrench	18	2

APPENDIX 4: TABLES

Mean Movement times (SD) in milliseconds:

Relations	Compatibility	Similarity	Mean (SD)
Related objects	Compatible	Similar	876.400 (114.216)
		Dissimilar	863.007 (116.611)
	Incompatible	Similar	888.483 (131.909)
		Dissimilar	880.371 (124.590)
Unrelated objects	Compatible	Similar	884.618 (124.193)
		Dissimilar	859.235 (112.600)
	Incompatible	Similar	874.385 (128.353)
		Dissimilar	884.470 (121.683)