The Context-Dependent Nature of Action Knowledge

Nicholas J. Shipp (n.j.shipp@herts.ac.uk)
Department of Psychology, University of Hertfordshire
Hatfield, AL10 9AB, UNITED KINGDOM

Frédéric Vallée-Tourangeau (f.vallee-tourangeau@kingston.ac.uk)
Department of Psychology, Kingston University,
Kingston upon Thames, KT1 2EE, UNITED KINGDOM

Susan H. Anthony (s.h.1.anthony@herts.ac.uk)
Department of Psychology, University of Hertfordshire
Hatfield, AL10 9AB, UNITED KINGDOM

Abstract

Recent theories of semantic memory have proposed that concepts are grounded in sensorimotor activity and mediated by the context from which the knowledge is drawn (Barsalou, 1999, 2003, 2008). Conceptual knowledge draws upon information from all modalities and therefore includes knowledge of associated object actions linked with both function and general movement (Bub, Masson, & Cree, 2008). The following experiment examined the conditions under which action information exerts an influence on experimental tasks particularly when taxonomic information is present. The experiment used a forced-choice triad task giving participants the choice of selecting between items that shared either a taxonomic or an action based relation with the target. The results showed that when the objects were presented as images on a white background (context-lean condition), participants were more likely to select the taxonomically related item. In contrast, when the same triads were presented as images being used in a functional scene (context-rich condition) they were more likely to select the action-related item. The results show that action knowledge is not automatic but is context-dependent. In line with views on embodied semantics, action-related information is drawn upon when objects are viewed and this influences task performance despite being unnecessary for the task.

Keywords: Action; Triads; Categorisation; Context.

Introduction

The traditional view of conceptual knowledge suggested that concepts are formed from amodal abstractions of the context in which they were previously encountered (Barsalou, 1999, 2003; Yeh & Barsalou, 2006). However an increasing number of researchers have shown that concepts are embodied within sensorimotor activity (Barsalou, 1999, 2008; Wu & Barsalou, 2009; Yeh & Barsalou, 2006). Embodied semantics takes the view that concepts are much more than decontextualised feature lists and that they reside within the same sensory-motor circuits in which they were first established (Aziz-Zedah & Damasio, 2008; Fernandino & Iacoboni, 2010). According to Barsalou (1999, 2003, 2008) the conceptual system does not record the images seen of an entity, but registers the concomitant neural experience. When encountering or re-instantiating the concept at a later date the conceptual system partially reactivates those neuronal patterns, thereby producing a simulation of the experience. Areas of the motor cortex that are active upon the initial object encounter will be reactivated and as such common actions associated with objects should readily come to mind when thinking of an object. Empirical work over the last decade has supported this view showing that semantic knowledge is embedded within physical actions which influences performance across a variety of cognitive tasks (Anelli, Nicoletti, & Borghi, 2010; Borghi, 2004; Borghi, Flumini, Natraj, & Wheaten, 2012; Bub & Masson, 2006; Bub, Masson, & Bukach, 2003; Chao & Martin, 2000; Creem & Proffitt, 2001; Iachini, Borghi, & Senese, 2008; Tipper, Paul, & Hayes, 2006; Tucker & Ellis, 1998, 2004; Vanio, Symes, Ellis, Tucker, & Ottoboni, 2008).

What has been particularly evident from the research is that action can play a role even in tasks where knowledge of associated action is neither required nor asked for. Borghi (2004) used a property generation task to show that when participants are asked to simply think about an object such as a car the first parts of the car that they name are those related to direct human interaction (e.g., the gearstick, steering wheel). The same parts were named first when participants were given a direct context to think about such as building the object. This would be in line with the view that thinking about the car activated the motor cortex and as such direct interaction became an influential feature in this task. Helbig, Graf and Keifer (2006) showed how actions are drawn upon in object recognition using a priming task. In their experiment participants were asked to name both a prime and a target object and showed that participants were more accurate in naming the target object when the prime was congruent in its action manipulation. Here the prime had a clear effect of activating the motor system and its relevant action knowledge that remained active for the target and hence identification was quicker. Helbig, Steinwender, Graf and Keifer (2010) used video primes of an agent performing an action on an object that was blacked out. Following the prime participants then saw an image of an object followed by a word, they were asked to identify if the word matched the object. Participants were again more accurate in their responses when the action seen in the prime matched the action of the following object. Further priming studies have shown similar action-based effects (Bub & Masson, 2012; Vanio et al., 2008).

Research has also shown that when participants are asked to make an action-based response they are typically faster and more accurate when action-based knowledge is taken into account. Jax and Buxbaum (2010) presented participants with objects that they termed as being either conflict or non-conflict. Non-conflict objects, they suggest, are objects that require the same action to both use and transport them (e.g., drinking glass). In contrast when the action of use is different from the action of transport (e.g., as for a calculator) the object is referred to as a conflict object. When participants were asked to place their hand on the objects as though they would use them they were faster for the non-conflict items over the conflict items. In addition they also found that generally participants were faster at making hand placements to pass the objects to another person rather than to use them. Osiurak, Roche, Ramone and Chainay (2013) showed the reverse effect when participants were physically asked to either pick up the objects in order to hit a ping pong ball or pass it to the experimenter. Here participants were faster at making use actions over transport. The authors attribute this to additional information being activated such as weight and solidity, which would not be activated if participants are simply asked to place their hand on the objects.

Yee, Chrysikou, Hoffman and Thompson-Schill (2013) found that performing concurrent actions along with a semantic decision task slowed down task performance. Their participants undertook a semantic decision task judging if spoken words were abstract or concrete while concurrently performing a three-step manual 'patty-cake' task. This involved participants placing two fingers, four fingers or the whole hand on its side onto a table top in a repeating manner while engaging in the semantic decision task. Yee et al. found a significant interference effect of performing such manual actions with slower decisions made when compared to participants who performed no concurrent task. The patty-cake task was found to have an increased interference effect on those objects that participants had greater levels of previous handling experience. No interference was found when participants performed a mental rotation task.

The Influence of Context

Research has shown that the context in which information is presented influences what type of conceptual knowledge becomes activated. Barsalou (1982) showed that while certain types of information are contextually independent and activated irrespective of the context other types of information can be contextually dependent and activated under certain circumstances. Barsalou showed that, in a property verification task, participants were quicker to verify that a basketball can float when given a context requiring someone to use one as a floatation device compared to verifying whether a basketball can bounce. Therefore such information would be contextually dependent as it does not always come straight to mind for this task but varies according to context. In contrast participants showed no difference in verifying sentences regarding how skunks have an unpleasant smell across different conditions. This would be regarded as contextually independent being drawn upon across different contexts. In supporting such findings Borghi et al. (2012) showed that activation of object affordances was contextually dependent. Participants were shown object pairs that were related either functionally (*paper* + *scissors*), spatially (*stapler* + *scissors*) or had no relation (*bottle* + *scissors*). In addition to this the pairs were also shown with either a hand with a functional grasp on one of the objects, a manipulative grasp, a hand present but not holding either item or with no hand present. The participants were quicker and more accurate at making decisions on the objects being related or unrelated when object pairs shared a functional context. Participants were also faster when pairs were presented with a functional hand grasp rather than a manipulative grasp, however overall responses were faster when the images were presented with no hand. Items that share the same function also share a related goal. As such it is possible that participants drew upon the related goal of the items that in turn decreased the reaction time between them. Since manipulative pairs share only a spatial context and no related goal they were slower than the functional pairs.

The Present Experiment

The first aim of the current experiment was to explore the role that action plays in category formation when it is presented in conjunction with category membership. It should be noted that for the purposes of this experiment action is defined as the direct interface between objects and the human body. For example the action of a rifle would be the grasp made by the hand around the handle, rather than action in terms of the act that can be carried out using a rifle. Many items that are action related also share category membership. For example an orange and a banana both require a peeling action and also belong to the same category of *fruit*. In addition, many items can share an action without sharing category membership such as a rifle and a water pistol which both require a grasp of the handle in the same fashion but are not both weapons. Therefore a task was designed in which category membership could be directly pitted against the action of interfacing with an object when using it in its functional capacity. Using this method it could be tested if participants would always choose category membership or if action knowledge would be drawn upon in line with recent views on embodied semantics. The experiment used a forced-choice triad task. This basic task has been used to demonstrate the influence of situational (thematic) information (Lin & Murphy, 2001; Murphy, 2001) when previously only taxonomic (shared property) information would have been predicted to guide choices. In Lin and Murphy's (2001) studies, the choice items were selected to share either a taxonomic or a thematic relation to the target. For example the target *bee* was presented with *wasp* (taxonomic similarity) or *honey* (thematic similarity). In a similar manner to Lin and Murphy, participants in the present experiment were presented with a target and two choice options, only one of which shared an action with the target. Based on the previous research showing the strong role of action knowledge in a range of tasks based on category knowledge, we predicted that participants would be more likely to select the action-

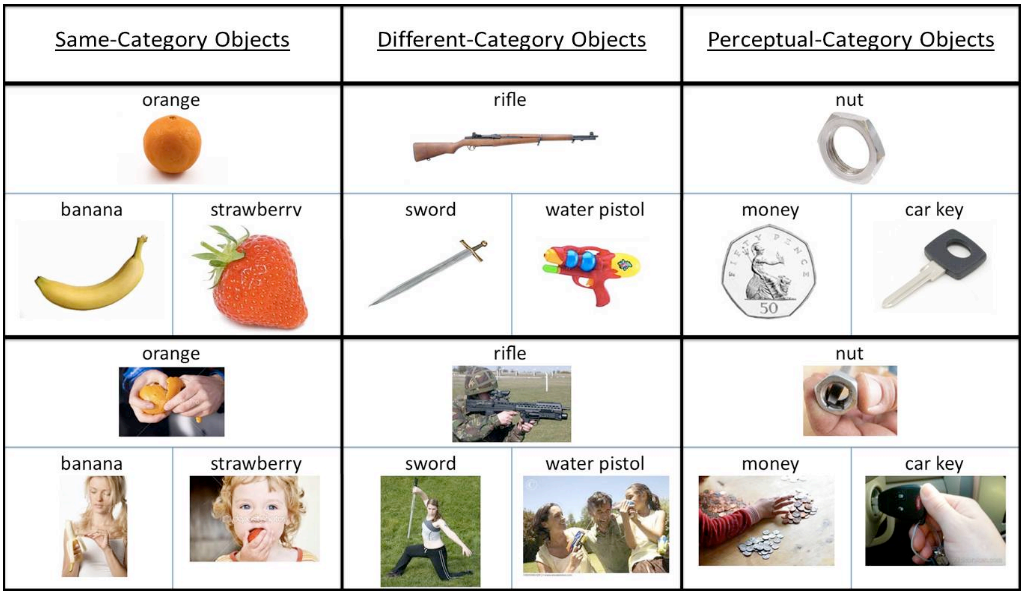

Figure 1: Examples of stimuli employed in the experiment. From left to right: Same Category Object triad, Different Category Object triad, and Perceptual Category Object triad in the context-lean condition (top panels) and in the context-rich condition (bottom panels).

related item over the taxonomic choice only when it too shared a taxonomic relation to the target. When the action-related item bore no taxonomic relation to target, we predicted that participants would be more likely to select the taxonomic choice.

The second aim of the experiment was to investigate the nature of action information and whether its activation is contingent on the context of categorisation. The triads shown were manipulated between subjects based on context. Participants either saw the objects on a white background (context-lean condition) or shown within an action based scenario with the objects being used by an agent (context-rich condition). It was predicted that in line with Borghi et al. (2012) the action choice within the triads would be selected more often when the images are shown within a functional context.

Method

Participants

Fifty undergraduate students (36 females) from the University of Hertfordshire participated in return for course credit with a mean age of 25.3 years (*SD* = 7.9, Range = 18-49).

Materials

The triads were based on the standard design of a target item followed by two items from which a choice could be made. Since the aim of the research was to compare the effect of action knowledge both alongside and set against taxonomic information, two sets of triads were initially designed, namely same-category object (SCO) triads and different-category object (DCO) triads (see Fig. 1). In the SCO triads participants saw a target (e.g., *orange*) and two choice items (e.g., *banana* and *strawberry*) which all belonged to the same category (*fruit)* as confirmed by pilot work. Of these choice items both share category membership with the target and in addition *banana* also shares a motor action with *orange*. In the DCO triads, one choice item shared category membership with the target but not an action (*rifle* and *sword*). The remaining choice item shared a motor action with the target but not category membership (*rifle* and *water pistol*).

In order to test the effect of context two sets of images were collected. The first set showed the objects against a white background (context-lean condition). The second set projected the objects being used in a functional context (context-rich condition, see Fig. 1). Twenty participants not used in the experiment took part in pilot work to ensure that the SCO and DCO triads were matched in terms of category membership and the action used to functionally interact with them. Fifteen of each triad set were initially designed and piloted. Using a Chronbach's alpha level of .7 as a threshold criterion, the final sets of SCO and DCO items were composed of 10 triads of each type.

A third set of triads (PCO) was designed based on the results of experimental pilot work. It seemed possible that participants might select the choice item sharing an action not because they shared an action, but because they shared perceptual properties. For example pencils and paintbrushes share perceptual properties, in part as a function of the ergonomic constraints that guide their design. Using the triads described above it is not possible to ascertain whether such items are selected because of action or because they look the same. In the PCO triads neither of the choice items shared category membership with the target item. One of the choice items shared an action with the target but few perceptual features (*nut* and *car key*). The remaining choice item shared perceptual features with the target but not an action (*nut* and *money*). The PCO triads were again presented in the same context-lean/context-rich manner as the SCO and DCO triads (see Fig. 1). Twenty participants not used in the experiment took part in pilot work to ensure that the PCO triads were matched in terms of perceptually relevant features and the action used to functionally interact with them. Fifteen PCO triads were initially designed and piloted. Using a Chronbach's alpha level of .7 as a threshold, a final set of 10 PCO triads were selected. Thus the experimental material was composed of 30 triads consisting of 10 SCO, DCO and PCO triads.

Procedure

The experiment employed a 3x2 mixed design where triad type was a repeated measure factor and context was a between subjects factor. The main dependent measure was the percentage of action choices calculated for each set of triad type in both context conditions. Stimuli and task instructions were presented on a 15" Macintosh laptop. Participants were instructed to "Please indicate which of the two items goes best with the item at the top of the screen", as they were in Lin and Murphy (2001). A fixation cue was presented on the screen for 1000ms after which the cue disappeared and the target word appeared along with the appropriate picture depending on which condition the participant was assigned to. After 1500ms the two choice options appeared beneath the target alongside the appropriate images. The triad remained on the screen while participants made their choice. Participants were instructed to press the 'a' key to choose the item on the left-hand side of the screen and the 'l' key for the item on the right-hand side of the screen. The choice items were counterbalanced across the triads so that in half the triads the action choice appeared on the left hand side while in the remaining half the action choice appeared on the right. After they had made their choice the triad disappeared and the fixation cue appeared again for the next triad.

Results

The mean percentage of action choices for each of the three triad types in both the context-lean and context-rich conditions are illustrated in Figure 2. As can be seen, the SCO triads produced the highest percentage of action-related responses in both the context-lean (61%, *SD* = 15%) and the context-rich condition (70%, *SD* = 15%). The action choice was selected least often with the DCO triads, though the mean was greater in the context-rich condition (53%, *SD* = 21%) than in the context-lean condition (32%, *SD* = 13%). In the PCO triads participants chose the action item less often than the perceptual item in the context-lean condition (48%, *SD* = 20%) but more often in the context-rich condition (69%, *SD* = 14%). For all three triad types participants selected the action choice more frequently when contextualised. A 3x2 mixed analysis of variance revealed that the main effect of context was significant, F (1, 48) = 39.22, $p <$ .001, η^2 = .45. Participants were more likely to select the action item in the context-rich condition when pictures of the objects were shown in a functional context. The main effect of triad type was also significant, F (2, 96) = 22.77, $p <$ .001, η^2 = .32. Post hoc analyses using the Bonferroni adjustment showed that participants selected more action choices overall on the SCO triads than in both the DCO triads ($p <$ .001) and the PCO triads (p = .031). Participants also selected more action choices in the PCO triads than in the DCO triads (p = .001). The interaction between triad type and context was not significant, F (2, 96) = 2.33, p = .10, η^2 = .05.

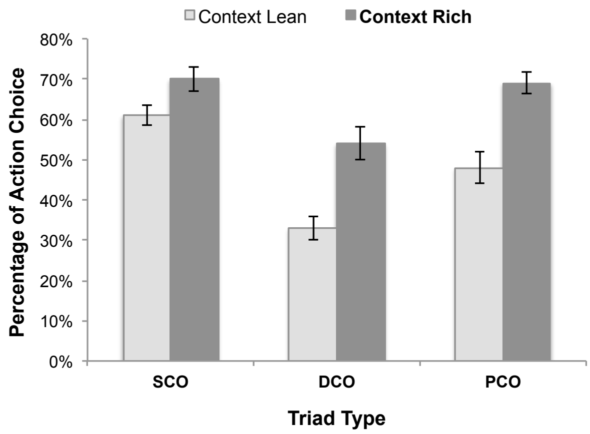

Figure 2. Mean percentage of action choices with Same Category Object (SCO), Different Category Object (DCO), and Perceptual Category Object (PCO) triads in the context-lean condition (light grey bars) and in the context-rich condition (dark grey bars). Error bars are standard errors of the mean.

Discussion

The experiment reported here sought to investigate the role of action in shaping categorical decisions. The first aim was to measure how action knowledge was used in the forced-choice triad task when pitted both against and alongside taxonomic information. The results from the different-category object (DCO) triads showed that when action knowledge was pitted against taxonomic information participants primarily grouped items together based on taxonomic information. For example participants were more likely to put *rifle* with *sword* rather than *water pistol*. The finding that shared action alone could not overcome taxonomic constraints is perhaps not surprising given the central role that functional knowledge plays in category membership. Participants were most likely to select the action choice when it was combined with taxonomic information, as with the same-category objects (SCO), showing that knowledge of action is perhaps insufficient on its own to act as a basis for category membership. Therefore while shared action may not be considered a sufficient basis in which to form categories as gauged by this task, it does appear to have an additive effect increasing the shared relations between two items. The perceptual-category object (PCO) triads were designed specifically to determine whether participants were selecting the items based on shared action or shared perceptual properties. If participants were drawing upon action knowledge then in such pairs where the choice comes down to a shared action or perceptual choice they should pick the action. In contrast if perceptual information is driving choices then participants should pick the item that looks more similar. The results showed that action knowledge was more likely to be used on the PCO triads over perceptual similarity when shared category membership was removed. Therefore, we can infer that participants were drawing upon knowledge of how they interacted with the objects rather than how they looked. As revealed with the SCO triads, participants were most likely to group items together when they shared both category membership and a functional action. The use of the perceptual-category object triads showed that this was not due to shared perceptual features between items that share an action. However, when participants were asked to choose between either a shared action or category membership in the DCO condition, participants were most likely to choose the latter until such items were shown in a functional context.

The second aim of the experiment was to see if action knowledge is drawn upon in all situations or whether its use in such tasks is context-dependent. The results showed that when participants saw the items in the context-rich condition they were more likely to select the action related item. It is possible that when participants viewed the images in the context-lean condition, action-related knowledge was simply not sufficiently salient to greatly influence choices over and above the other commonalities between items. In contrast, the context-rich condition clearly showcased the objects being used in their standard capacity and as such the shared actions presented themselves more clearly as 'features' that could influence the choice. The relevance of action knowledge in driving categorisation intuitions is thus contingent on the context of presentation. This suggests that viewing items without a context is not necessarily enough to instantiate action knowledge and this is in line with previous research (Borghi, Bonfiglioi, Lugli, Ricciardelli, Rubichi, & Nicoletti, 2007; Borghi et al., 2012). In the same way that object properties have been shown to be context-dependent (Barsalou, 1982), the actions associated with objects also seem to become most salient and influential in this passive task in the presence of context.

In order to fully extend this research a new set of triads would need to be designed in which the items share an action along with taxonomic information, but do not share perceptual properties. While this would be the ideal condition there might be insurmountable constraints on designing the material required to run this experiment: In aiming to optimise the functionality of the human-artefact interface, objects that share an action will invariably share perceptual properties. For example pencils and paintbrushes look similar as they are designed to be used with a pinch grip and rest within the thenar space of the thumb and index fingers. Items sharing category membership further confines this problem as items become more similar to each other based on the ergonomics of design. Therefore it might prove impossible to find items that require the same method of interaction/operating but that did not share the perceptual properties linked with that action.

In conclusion the data reported here indicate that action-related information is influential when participants are engaging in categorisation tasks that do not require any action to be made. This effect is made even more evident when the presentation of the objects is embedded in an action-relevant context. It has further been shown that while perceptual information plays a strong role in categorisation there are circumstances when action knowledge is chosen over perceptual information. The results of the experiment have established conditions under which action knowledge informs categorisation intuitions in a passive cognitive task.

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