ACTPSY 949
15 December 2003 Disk used ARTICLE IN PRESS No. of Pages 28, DTD = 4.3.1

ELSEVIER

Acta Psychologica xxx (2003) xxx–xxx

acta psychologica

www.elsevier.com/locate/actpsy

Object concepts and action: Extracting affordances from objects parts

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Received 17 April 2003; received in revised form 13 November 2003; accepted 21 November 2003

Abstract

Two experiments with a part-generation task show that rated salience and production order of parts in artifacts are first predicted by their relevance for canonical actions, but also that they vary, depending on the current situation.

In three further experiments participants read sentences describing actions (e.g., 'The woman shares the orange') followed by objects' parts from which it was easy or not to extract affordances (e.g., 'slice' vs. 'pulp'). They had to perform a part verification task or to evaluate whether or not the combination made sense. Parts from which it was easy to derive affordances were processed earlier and the combination was evaluated as the one which made more sense.

Overall, results support the view that sensory-motor simulations underlie conceptualization and that concepts are action-based.

PsycINFO classification: 2300; 2340
Keywords: Categorization; Action; Affordance; Conceptual knowledge

1. Introduction

1.1. General framework

Amodal views of conceptual knowledge assume that concepts, i.e., our knowledge units about categories, are represented through propositional symbols. The relationship between these symbols and their referents is arbitrary. Amodal views are usually

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0001-6918/$ - see front matter © 2003 Published by Elsevier B.V.
doi:10.1016/j.actpsy.2003.11.004

based on the premise that perceptual and motor experience is translated into amodal and abstract symbols (Fodor, 1975; Smith & Medin, 1981; for a recent powerful formulation of this view see Landauer & Dumais, 1997). So, for example, the concept 'cup' would be represented through propositional features such as 'has a handle,' 'you drink from it,' and so on. There is no relationship between the features we associate with the cup and the sensory-motor experience we have when we see a cup or drink from it.

A logical consequence of this vision of concepts is the assumption that the semantic system, where knowledge is "contained", is clearly differentiated from the other modular systems of perception and action (Rumiati & Humphreys, 1998; Tulving, 1972).

As far as research programs are concerned, the adoption of amodal views of conceptual knowledge has often led researchers to focus on the stable rather than on the flexible aspects of conceptual organization (see for example the critiques of Smith, 1995). This does not mean that symbolic amodal theories cannot account for or predict variability in conceptual organization (Landauer & Dumais, 1997). Simply, the source of this variability is ascribed to semantic relatedness between concepts and to frequency and is not attributed to the re-enactment of a sensory-motor experience.

Recently, in different fields, a different view of the relationship between cognition, perception and action has begun to gain credit (Thelen & Smith, 1994). In particular, it has been proposed that cognition is embodied, i.e., that it depends on the kind of experiences produced as a result of our having a body with a particular sensory-motor system. This view of cognition is clearly in opposition with the classical cognitivist view, according to which the mind is a device for manipulating arbitrary symbols. In line with this perspective, the view held by Gibson (1979) has been given new resonance. Many theories in various fields, from those regarding perception to those regarding attention, to language (Berthoz, 1997; Humphreys & Riddoch, 2001; Liberman & Whalen, 2000; Rizzolatti & Arbib, 1998; Rizzolatti, Riggio, Dascola, & Umiltà, 1987), share the idea that perception, action and cognitive systems cannot be considered as separated, and defend the claim that cognition is deeply grounded in sensory-motor processes. For example, in the field of vision studies, O'Regan and Noë (2001) have recently proposed that seeing is a way of acting, i.e., that it is a way of exploring the environment. Accordingly, the experience of seeing occurs when the organism masters the governing laws of sensorimotor contingency.

In the field of categorization, as well, a different view of conceptual knowledge has begun to gain credit in recent years. It has been argued that the existence of a translation process—from sensory experience into amodal symbols—is not necessary, nor is it plausible from an evolutionary point of view. In this perspective, concepts are conceived of as re-enhancement of neural activation patterns, directly referring to sensory-motor experiences (Barsalou, 1999; Barsalou, Simmons, Barbey, & Wilson, 2003).

Much neural evidence convergent with this view has been provided: in particular, proponents of the sensory-motor theory, on the basis of functional neuroimaging data, argue that conceptual knowledge does not constitute information which is physically distinct from modality specific input and output representation. On the contrary, "the features that define an object are stored close to the primary sensory and motor areas that were active when information about that object was acquired" (Martin, Ungerleider, & Haxby, 2001, p. 1023; for a review adopting a different position, see Mahon & Caramazza, in press).

An implication of this view is that, because knowledge is anchored in experience, it cannot be separated from perception and action. In antithesis with the amodal view, recent studies show that perception, action and cognition are deeply related. This idea was anticipated by Gibson's (1979) theory, according to which perception is not a channel of information flow made of different processing stages (Sternberg, 1969) but it is deeply influenced by action and movement. Much neurophysiological evidence is consistent with the view of the reciprocal interaction of action intention and perceptual systems (Jeannerod, Arbib, Rizzolatti, & Sakata, 1995; Knoblich & Flach, 2001; Prinz, 1997; Ward, 1999). On the behavioral side, recent evidence indicates that the relationships between perception and action may be reciprocal. Tucker and Ellis (1998, 2001) have shown that the vision of an object may directly elicit action patterns independent of the intentions of the subject: for example, the vision of a cup elicits (affords) the action of grasping it, and the vision of objects different in size elicits different kinds of grasping (precision vs. power grasp). Bekkering and Neggers (2002) have shown that the intention to perform an action modulates visual processing by favoring the perceptual features that are related to action. They measured the accuracy of saccades in grasping and pointing to target objects that could have a different orientation (45° vs. 135°) and color (green vs. orange). They found that the first eye movement was more accurate in selecting a target object with a given orientation located in the midst of distractors when the object had to be grasped afterwards than when it had to be pointed to. There was no difference in errors between conditions when participants had to select an object with a predetermined color. Given that orientation is relevant for grasping but not for pointing, the results indicate that action planning influences visual processing. The fact that action intention (e.g., grasp vs. point) leads to different ways of focusing on visual properties can deeply influence theories on concepts. In this line, recent proposals argue that conceptualization has its basis in both perception and action, and that it has the adaptive role of preparing for situated action (Barsalou, 2002). Thus, concepts, i.e., our knowledge units, can be conceived of as the coding of possible interaction patterns with the world surrounding us (Glenberg, 1997).

A further implication of this view is that, because knowledge is grounded in bodily and situational experience, conceptual variability is highly stressed. In fact, depending on our kind of body and on the situation we are experiencing, different conceptual aspects are activated. Accordingly, concepts are conceived of as situated and embodied, because they vary depending on the situation and on the relations between their referents and our body (Barsalou, 1987, 1999; Smith & Samuelson, 1997).

A central notion for the view that "knowledge is for action"(Wilson, 2002) is that of affordance (Gibson, 1979), for two reasons: (1) because it demonstrates the close connection between perception and action, and (2) because it provides an understanding of the importance of variability and situationatedness. Affordances are ways in which a perceiver can interact with an object. Thus the notion of affordance is not an absolute one. Depending on the constraints of our body, on the perceptual characteristics of objects and on the situation at hand, different objects or different parts of objects may afford actions. When we are driving a car, its steering wheel may become particularly salient for guiding our actions, while when we are repairing a car, its motor may become more salient. However, regardless of the current situation, both the car's steering wheel and motor are probably more salient for the concept 'car' than other parts typically less salient for acting, such as the roof.

1.2. Aim and hypotheses

If the claim that "knowledge is for action" is true, an important function of concepts may reside in the role they play when one is preparing for situated actions (Barsalou, 2002). The advantage of preserving perceptual and motor characteristics of conceptual referents may reside in facilitating our interaction with objects.

The aim of this paper is to verify whether objects are represented as patterns of potential actions by focusing on their parts. But what is a part? Different proposals have been advanced, in order to define parts. For example, Biederman (1987) proposed that it is possible to segment objects into a set of 3-D volumetric primitives called geons. In a different view, Hoffman and Richards (1984) have proposed that individuals are more likely to identify a particular patch of shape as a part because it lies between two points of extreme negative curvatures, rather than assuming that objects are parsed into primitive shapes. Here, parts are defined in a very broad sense, as any fragment or component of an object-stimulus. Given that the studies proposed involve three tasks which imply a linguistic mediation—a part production, a part verification and a sensibility-evaluation on parts task—parts with an easily expressible name will have an advantage over components of objects without a name.

Parts are particularly important because actions are generally directed towards them. There is much evidence showing that objects are represented componentially (Biederman, 1987), and that parts play a special role for object concepts, especially for basic level ones (Murphy, 1991; Rakinson & Butterworth, 1998; Schyns & Murphy, 1994; Tversky, 1989; Tversky & Hemenway, 1984). In particular, as the action intention selects perceptually relevant properties in perception, in conceptualization different parts should also be activated depending on the activated action and situation.

If concepts are not represented as patterns of potential actions,

1a. the salience of a part should be independent of the role parts play for guiding acting;
1b. the salience of a part should not vary depending on the currently activated action.

If object concepts are represented as embodied and situated entities (Barsalou, 1999; Pecher, Zeelenberg, & Barsalou, 2003),

2a. the salience of a part should depend on the role parts play for canonical actions directed towards an object, i.e., the most important parts in an object concept should be the ones affording the more frequent actions performed with it;
2b. the salience of a part should vary depending on the currently activated action.

Hypotheses 2a and 2b are not conflicting; in fact, it is plausible that not all possible affordances are necessarily activated during a simulation, only affordances elicited by canonical actions as well as affordances relevant for the current goals (Kaschak & Glenberg, 2000; Zwaan, Stanfield, & Yaxley, 2002). The term "simulation" refers to the fact that we may simulate an object, for example a car, in its absence (Barsalou, 1999), because we have integrated the properties of the object in a coherent and organized system. Thus we might simulate cars' parts by re-enhancing the sensory-motor experience we have had with them. The same is true for event sequences. For example, the simulation of the event sequence of moving a table focuses on the actions involved in lifting and pushing it, but not on the experience of eating on it.

1.3. Overview of the present experiments

To test these hypotheses in Experiments 1 and 2 a feature generation task was used, which is widely assumed to assess the way concepts are represented (Tversky & Hemenway, 1984; Wu & Barsalou, submitted for publication).

Consider that modal views naturally predict that concepts, similarly to percepts, have perspectives, i.e., that activated features are best predicted by action and the current context. It would be reductive, however, to argue that amodal theories cannot explain these effects. Proponents of such theories might account for such results by arguing, for example, that certain concept parts have stronger semantic associations with certain situations than with others.

In particular, proponents of the amodal view might claim that feature production tasks are not sufficiently informative, as their results might be explained by the fact that there are simply stronger lexical associations, say, among words denoting parts within a given perspective than across different perspectives. For this reason in Experiments 3 and 4 a part verification task was used, and in Experiment 5 a sensibility-rating task of words and sentences was used. These methods allow an easier control of the association degree between words denoting parts and words and sentences denoting situations, and make it possible to rule out the hypotheses that the results might be due to semantic associations rather than to the creation of mental simulations of the objects.

Experiment 3 tests with a part verification task the hypothesis that different parts are activated depending on the action expressed by a sentence. If it is true that processing a sentence like 'He grasped the knife' activates a mental simulation of the scene, and if it is true that objects are represented componentially (Biederman, 1987), the part 'handle' following the sentence should be verified faster than the part 'blade', due to the fact that the part 'handle' better affords the action of grasping a knife than the part 'blade'. Consider, however, a possible objection to this experiment. The demonstration that different actions activate different parts may simply show that conceptual organization is variable, but not that concepts are represented through simulations preserving their perceptual and motor characteristics. Simply, such a result could be explained by a semantic network account: the verb 'grasp' may be more semantically associated with 'handle' than with 'blade', while the verb 'cut' may be more semantically associated with 'blade' than with 'handle'.

In order to rule out a semantic network account, in Experiments 4 and 5 parts were selected which were not semantically associated to a given action, but which, due to their perceptual features, might or might not afford a particular action (see Glenberg & Robertson, 2000). Parts from which it is easy to extract affordances will be called affording parts. For example, the neck of a bottle can more easily afford the action of putting it down than its cork, even though neither the word 'neck' nor the word 'cork' are strongly semantically associated with the sentence expressing the action of putting something down. Experiment 4 tests whether affording parts are processed quicker than non-affording parts in a part verification task; Experiment 5 tests whether affording parts are considered more sensible in the context of sentences compared with non-affording parts. If affording parts are processed earlier and evaluated as being more plausible than non-affording parts, this advantage cannot be due to the semantic relatedness between words denoting parts and sentences. Thus, the results will favor the view according to which concepts are simulations preserving perceptual and motor characteristics of objects. A possible advantage of preserving perceptual characteristics of objects is to prepare for situated action (Glenberg, 1997), thus facilitating interaction with the object.

2. Experiment 1

In this experiment the type of simulated interaction with objects was manipulated: three groups of participants were required to imagine using/acting, building, or seeing objects. For the critical objects they were also required to produce parts. If hypothesis 1 is true, i.e., if concepts are represented through amodal and arbitrary symbols and are stable across situations, then (a) parts relevant for acting should not be produced more frequently across conditions and earlier than other parts; (b) the same parts should be generated in the three situations and in the same production order. If hypothesis 2 is true, i.e., if concepts are represented as patterns of potential actions in terms of perceptual symbols, then (a) parts relevant for canonical actions should be produced across all situations and should be produced earlier than other parts; (b) in the building and vision situation there should be an interaction: parts more relevant for building should be produced more frequently and earlier in the building than in the vision situation; the opposite should be true for the vision situation.

2.1. Participants

Forty-eight students of the University of Bologna, native Italian speakers between the ages of 19 and 24, volunteered for the experiment. Sixteen participants were randomly assigned to each of the three groups between participants conditions.

2.2. Material

Twenty-eight concept names were selected, 14 of which referred to objects that could be used/acted upon, built or seen, 14 of which referred to objects or entities that could not (e.g., phantom, alien). Special care was taken in selecting the seven critical concept-nouns among the 14 concepts referring to objects which could be used/acted upon, built or seen: bicycle, car, hi-fi, mixer, motorbike, piano, and washing machine. A pilot study was run in which six independent participants evaluated a list of 15 complex artifacts concept-nouns, chosen because they have parts differently relevant in the three situations of acting/using, building and seeing the objects. Note that the Italian words used contain no cues as to possible parts or actions, as their English counterparts do. The seven critical concept-nouns were the concepts which, according to all raters, were characterized by the fact that they have parts which are differentially relevant for each of the three situations. In fact, all of the selected artifacts, regardless of their size and complexity, are characterized by having three different kinds of parts. They all have external parts, often protruding from the object's main structure, which typically afford actions: for example the car's steering wheel, the handle of a bicycle and of a bike and the keys and buttons of the washing machine, the hi-fi and the mixer. They also have external parts, which do not protrude from the object's main structure but often constitute it. These objects are typically larger than the first ones but typically do not elicit goal-directed actions, as for example the car's roof and sides, the structure of the hi-fi, the tail of the piano. Finally, all the selected artifacts have internal parts which determine the way the objects work but are not perceptible from the outside and are not relevant for canonical action with the object, even though they are very important for building the objects, as for example the motor of the car, the chain of the bicycle, the wires of the hi-fi.

2.3. Procedure

The paradigm used was very similar to that developed in Borghi and Barsalou (2001). Participants, who were individually interviewed, had to perform an imagery decision task, i.e., they were asked whether they could imagine themselves or somebody else either using, building or seeing an object, depending on the experimental condition. Participants could answer 'yes' or 'no' to the question, which was repeated for each concept. Immediately after having answered 'yes' or 'no' for the seven critical concepts they were also asked to produce the parts of the objects they referred to. The part-generation task was embedded within an imagery decision task in order to avoid rendering the task transparent.

2.4. Transcription and rating

The tape-recorded interviews were transcribed. For each participant both the parts produced and the sequential position in which each part was produced (first, etc.) were reported.

Four independent raters were asked to evaluate on a seven-point scale the importance of each part produced for acting/using, building and seeing each object. Each rater saw the produced parts in a different random order and did not know in which situation (action/use, building or vision) they had been produced.

2.5. Results

2.5.1. Frequency

The frequency of the parts produced in the action/use situation ($M = 3.71$) was lower than that of the parts produced in the build ($M = 4.89$; Newman–Keuls $p < 0.03$) and vision situations ($M = 4.95$; Newman–Keuls $p < 0.05$) ($F(2, 45) = 3.61$, $MSe = 2.15$, $p > 0.05$).

2.5.2. Rated perspective

The scaled ratings were applied to the individual protocols in order to see whether, for a given protocol, the parts produced reflected one perspective more than the other and whether the parts reflecting a given perspective were produced first.

2.5.2.1. Parts dominant in one perspective. The parts whose average rating in one perspective was at least one point higher than the max of the average ratings of the two other perspectives were selected. For each concept there was a sub-group of parts dominant in each perspective. For example, for the concept 'car,' 'accelerator' and 'pedals' were dominant in the action/use perspective, 'transmission' in the build perspective, and 'windshield' in the vision perspective.

2.5.2.2. Ratings. The average rating of each part for each perspective (act/use, build and vision) was multiplied by the frequency of the produced parts $(0, 1)$ for each participant. Consider that in studies on categorization with feature generation tasks the features produced are typically coded according to a norm—for example, the features produced for a given concept are distinguished according to thematic properties, taxonomic properties, attributive properties etc. (Borghi & Caramelli, 2003; Lin & Murphy, 2001). This presupposes that the same relation cannot be at the same time both thematic and taxonomic, or that the percentage of overlap is not high. Typically, two people code the properties produced according to a norm (for examples, see Barsalou, Solomon, & Wu, 1999), and the frequency of the coded properties are treated with statistical analysis. In this study it would be difficult and simplistic to code each part as relevant only for one situation—building, action/use, vision. For this reason, four coders, instead of two, were asked to rate the importance of each part for each perspective using a seven-point scale (instead of a yes or no coding). This made it possible to obtain a weighted coding instead of a dichotomic coding (e.g., to consider each property as linked exclusively with vision, action, or building). On the frequency of the coded parts an ANOVA was performed.

The design was mixed in the ANOVA, because Situation (action/use, build and vision) was manipulated between participants and Ratings within participants. The two main effects of Situation ($F(2, 45) = 5.70$, $MSe = 0.11$, $p < 0.01$) and Ratings ($F(2,90) = 63.51$, $MSe = 0.049$, $p < 0.01$) were significant, as well as the interaction ($F(12,90) = 13.44$, $MSe = 0.049$, $p < 0.01$). Overall, across situations the parts produced were those which were rated higher according to the action/use perspective than both the build and vision perspectives (Newman–Keuls, $p < 0.01$). This indicates that the canonical perspective activated for objects is the action/use one. However, the interaction indicates that in the build Situation participants produced mainly parts relevant to building, while in the vision Situation they produced parts relevant to vision (Newman–Keuls, $p < 0.01$). This shows that object parts are differently activated depending on the perspective with which they are accessed (see Fig. 1).

2.5.2.3. Ratings × Position. The average rating on each part for each perspective (action/use, building and vision) was multiplied by the position of the produced part by each participant according to the following formula: $(n + 1 - p)/(n - 1)^{*}r$, where n is the total number of parts produced by each participant for each concept, p the position in which each part was produced and r the average rating on that particular

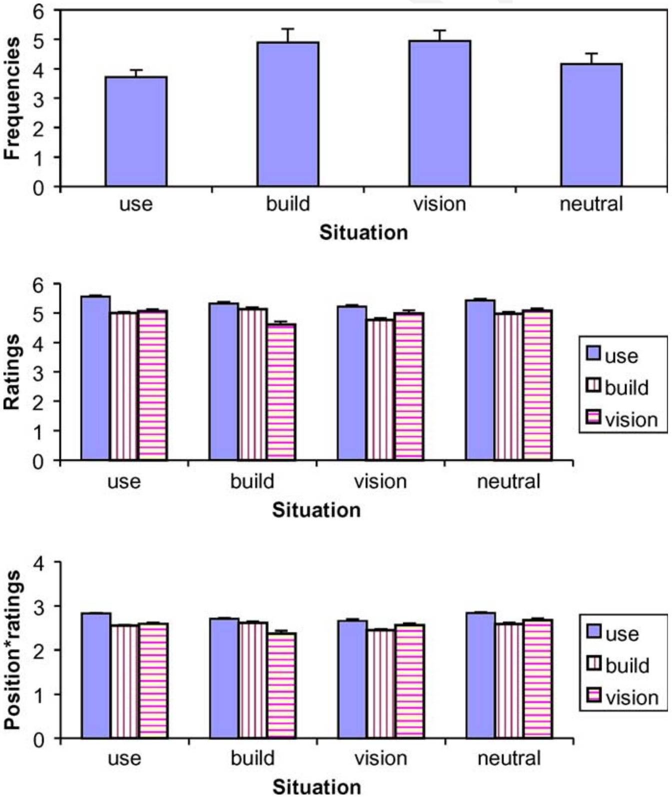

Fig. 1. Experiments 1 and 2. Frequency and rated Perspective by Frequency and by Position of the produced parts in each Situation.

part (for a similar procedure, see Wu & Barsalou, submitted for publication). This normalized p, the position in which each part was produced, in relation to n, the total number of parts produced by each participant, so that, for example, the first position within a total of 10 properties was considered as more relevant than the first position within a total of two properties.

Overall, across the three situations the parts relevant for action/use were produced earlier than those produced in both the building and vision situations (Newman–Keuls, $p < 0.01$). The interaction between building and vision indicates that the parts produced earlier in the building Situation are parts relevant for building, in the vision Situation are parts relevant for vision (Newman–Keuls, $p < 0.01$). In the ANOVA the two main effects of Situation ($F(2,45) = 7.22$, $MSe = 0.02$, $p < 0.01$), Ratings × Position ($F(2,90) = 36.43$, $MSe = 0.02$, $p < 0.01$), and the interaction ($F(4,90) = 8.36$, $MSe = 0.02$, $p < 0.01$) were significant. The results obtained confirm that object concepts are conceived in terms of their affordances, i.e., of the parts which elicit actions, but they also demonstrate that depending on the situation, different parts are activated.

2.6. Discussion

The results support the predictions of the embodied and situated view of concepts. In fact, parts produced more frequently and earlier across situations are those rated as relevant for canonical actions, i.e., for using the object (hypothesis 2a). In addition, depending on the kind of simulated interaction with objects (building vs. vision), different parts become salient for concepts (hypothesis 2b). Thus conceptualization is both body and situation dependent.

3. Experiment 2

If object concepts are represented as action-based, then in a neutral condition the parts relevant for actions should be those which are rated as most important and produced earlier. Experiment 2 represents a control experiment of Experiment 1, consisting of a simple part-generation task, performed without asking participants to simulate a particular situation.

3.1. Participants

Sixteen students of the University of Bologna, native Italian speakers, volunteered for the experiment.

3.2. Material

The same seven critical trials used in Experiment 1 were used in this experiment.

3.3. Procedure

The procedure differed from that of Experiment 1 only in that participants, who were individually interviewed, did not perform the imagery decision task but only the part-generation task.

3.4. Transcription

As in Experiment 1 the interviews were transcribed and for each participant both the parts produced and the position in which they were produced were recorded.

3.5. Results

3.5.1. Rated perspective

The scaled ratings of Experiment 1 were applied to the individual protocols of Experiment 2 in order to see whether, for a given protocol, the parts produced reflected one perspective more than the other, and whether the parts reflecting a given perspective were produced first.

3.5.1.1. Ratings. As in Experiment 1, the average rating on each part for each perspective (action/use, building and vision) collected in Experiment 1 was multiplied by the frequency of the produced parts $(0, 1)$ by each participant in this Experiment.

In order to see whether the parts produced in the neutral Situation reflected one perspective more than the others, an ANOVA was performed with the variable Ratings at three levels (action/use, building and vision), manipulated within participants. The parts produced were those which were rated higher according to the action/use perspective than both the building and vision perspectives ($F(2, 30) = 31.81$, $MSe = 0.027$, $p < 0.01$) (Newman–Keuls, $p < 0.01$). This confirms the trend found in Experiment 1.

3.5.1.2. Ratings × Position. The average rating on each part for each perspective (action/use, building and vision) was multiplied for the position of the produced part by each participant following the same formula used in Experiment 1. The results of the ANOVA show that the parts produced earlier are those which obtained higher ratings in the action/use perspective than in both the building and vision perspectives ($F(2, 30) = 21.56$, $MSe = 0.01$, $p < 0.01$) (Newman–Keuls, $p < 0.01$).

3.6. Discussion

The results of Experiment 2 show that when participants are not asked to simulate objects in a specific situation the saliency of object parts depends on their role for action (hypothesis 2a). In order to better disentangle the results, the data of Experiments 1 and 2 were compared directly.

4. Comparison between Experiments 1 and 2

If hypothesis 2a is true, i.e., object concepts are patterns of potential actions and the canonical perspective in which objects are represented is action/use dependent, then the results obtained in Experiment 2, i.e., in a part-generation task performed in a neutral condition, should resemble those obtained in the action/use condition of Experiment 1 and differ from those obtained in the building and vision situations of Experiment 1 (see Fig. 1).

4.1. Results

4.1.1. Frequency

The frequency of the parts produced in the four situations (E1 action/use, E1 building, E1 vision, E2 neutral) was compared. The average frequency of the parts produced in E2 was higher than that of parts produced in E1 action/use situation, but much lower than that produced in the E1 building and E1 vision Situation ($F(3,60) = 2.70$, $MSe = 2.10$, $p < 0.05$). Post hoc Newman–Keuls showed that the E1 action/use situation differs from both the E1 building ($p < 0.2$) and the E1 vision situations ($p < 0.03$). The E2 neutral situation does not differ significantly from any of the other situations.

4.1.2. Rated perspective

4.1.2.1. Ratings. An ANOVA was performed with the variables Situation at four levels (E1 action/use, E1 building, E1 vision, E2 neutral) and Ratings at three levels (action/use, building, vision). Both the E1 action/use and the E2 neutral situations had the same pattern of results differing from the other two situations. The two main effects of both Situation ($F(3,60) = 4.17$, $MSe = 0.126$, $p < 0.01$) and Ratings ($F(2,120) = 89.20$, $MSe = 0.04$, $p < 0.01$) were significant as well as the interaction ($F(12,120) = 10.798$, $MSe = 0.04$, $p < 0.01$). Post hoc Newman–Keuls shows that the E1 action/use and the E2 neutral situations do not differ but both differ from the other two situations (Newman–Keuls, $p < 0.01$).

4.1.2.2. Ratings × Position. The same result was found in the ANOVA on positions. The effects of Situation ($F(2,60) = 9.65$, $MSe = 0.02$, $p < 0.01$), Ratings × Position ($F(2,120) = 52.57$, $MSe = 0.02$, $p < 0.01$) and the interaction ($F(6,120) = 6.99$, $MSe = 0.017$, $p < 0.01$) reached significance. Again, the E1 action/use and the E2 neutral situations differed from both the E1 building and the E1 vision ones (Newman–Keuls, $p < 0.01$).

4.2. Discussion

Hypothesis 2a is confirmed. In fact, across the four situations the parts relevant for action/use were produced earlier than those produced in both the building and vision situations. In addition, the pattern of data obtained in the neutral situation strongly resembles that of the action/use situation.

It can be argued that the parts of artifact concepts which are activated in a neutral condition, and those which are activated earlier, are not those which are more visible or more important structurally, but those which are more relevant for acting with objects.

Consider, however, a possible objection to the previous experiments. A proponent of the amodal view might claim that a feature production task is not sufficiently informative, as the results of the first two experiments might also be explained by stronger lexical associations among words denoting parts within a given perspective than among words across different perspectives.

It is possible to respond to this objection both theoretically and from a methodological approach. From a theoretical point of view, it can be objected that lexical associations are grounded in and originated in perceptual and action experience. However, this argument might be considered too general.

Taking a closer look at the data, it can be said that Latent Semantic Analysis (LSA, Landauer & Dumais, 1997) would predict mostly situational effects, while the data show both canonical and situational effects. However, it can be argued that this is not completely true; in fact, the dominance of a situation across others might also be predicted by a word association account, without it being necessary to postulate a perceptual simulation account.

In order to rule out possible objections, different methods were used: a faster part verification task and a sensibility-rating task made up of words and sentences. These methods have the advantage of making it easier to control for semantic associations between concept-nouns and sentences referring to situations.

Consider a further point. It might be argued that the results of Experiments 1 and 2 hold only for complex artifact concepts, and more specifically for artifacts which can be manipulated and with which we generally perform actions, such as bicycles in comparison to statues. For this reason in Experiments 3–5 a further variable was introduced, the difference between concept kinds. Different studies, both behavioral and neural, show that artifacts elicit functional rather than perceptual attributes (Keil, 1989) and suggest that function and manipulation knowledge are critical for artifacts (Buxbaum, Schwartz, & Carew, 1997; Buxbaum, Sirigu, Schwartz, & Klatzky, 2003; Buxbaum, Veramonti, & Schwartz, 2000; Chaigneau & Barsalou, in press; Sirigu, Duhamel, & Poncet, 1991; for reviews see Borghi, submitted for publication; Capitani, Laiacona, Mahon, & Caramazza, 2003; Martin & Caramazza, 2003; Pulvermüller, 1999, 2003). Neuroimaging studies show that artifacts activate pre-motor areas whereas living kinds activate brain regions involved in visual processing (Chao & Martin, 2000; Martin, Wiggs, Ungerleider, & Haxby, 1996). Thus it can be hypothesized that artifacts' affording parts are more influenced by the selected action than natural kind affording parts.

5. Experiment 3

The aim of Experiment 3 is to show with a part verification task that, depending on the actions expressed by a sentence, different parts of an object are activated. For example, the part 'slice', due to its perceptual features, better affords the action of dividing an orange than the part 'pulp'.

Both artifacts and natural kind concepts were used in order to see whether the hypothesis according to which concepts are patterns of potential actions holds for both kinds of concepts or only for artifacts.

5.1. Method

5.1.1. Participants

Nineteen students of the University of Bologna were recruited for the experiment. A within-subjects design was used.

5.1.2. Material

The material consisted of 48 sentences of the form subject–verb–object (see Appendix A). Each sentence could be followed by two nouns indicating a part of the object, for a total of 96 trials. The object of half of the sentences was a basic level natural kind (e.g., flower), the object of the other half was a basic level artifact (e.g., shirt). There could be either congruency between the action expressed in the sentence and the object part ('the child divided the orange—slice'; 'the child tasted the orange—pulp') or not ('the child divided the orange—pulp'; 'the child tasted the orange—slice'). Each part was presented only in combination with one concept (e.g., 'slice' was presented only in the two different sentences whose object was 'orange'). The presented parts were controlled for length and familiarity. The same 96 sentences were presented followed by nouns that indicate parts, but not parts of the object mentioned in the sentence (e.g., 'the child divided the orange—lever'), for a total of 192 sentences.

5.1.3. Procedure

The experiment started with 16 practice trials to familiarize the participants with the task. During each trial each participant first saw a horizontally centered fixation point; then a sentence appeared (e.g., 'The girl read the book'); after 750 ms the sentence disappeared and a part noun appeared.

Participants had to press a button with their dominant hand as quickly as possible to indicate 'yes, the noun is a part of the object of the sentence' (e.g., 'page'), and a button with their not dominant hand to indicate 'no, it is not a part of the object of the sentence' (e.g., 'lever'). Participants were told to read the whole sentence and not just the object of the sentence.

5.2. Results

Analyses were conducted on both the RTs and the frequency of correct judgements. The analyses were performed only on the trials requiring a positive response. RTs were removed for target trials on which errors occurred. To reduce the effect of the outliers, RTs higher or lower than the average ± 2 standard deviations for each participant for each condition were eliminated, corresponding to 1.58% of the data.

The ANOVA on response times showed an effect of congruency of part and verb. The difference in accuracy was also significant. Affording parts were processed faster ($M = 970$ ms instead of 1076 ms) ($F(1,18) = 5.38$, $MSe = 39\,721.49$, $p < 0.03$) and elicited less errors ($M = 1.82$ instead of $M = 2.58$) than non-affording parts ($F(1,18) = 10.12$, $MSe = 1.09$, $p < 0.01$). In the ANOVA on RTs the interaction between affordance and kind of concepts was also significant ($F(1,18) = 8.72$, $MSe = 40\,000.31$, $p < 0.01$); post hoc Newman–Keuls showed that this was due to the fact that non-affording parts of artifacts were processed slower than affording parts of artifacts and both affording and non-affording parts of natural kinds ($p < 0.01$) (see Fig. 2).

5.3. Discussion

The results indicate that different actions expressed by sentences activate different object parts, i.e., that they activate the object parts which can be better combined with the actions. Overall, affording parts, i.e., parts which are more congruent with the action mentioned in the sentence (e.g., 'the woman ate the watermelon—seeds') are processed faster and elicit less errors than non-affording parts (e.g., 'the woman ate the watermelon—skin'). The results support the argument that conceptual organization is variable, because concepts' perceptual features are differentially accessed depending on the activated action (Barsalou, 1987).

In addition, they show with a quick part verification task that object concepts are activated componentially and not holistically (Biederman, 1987), because different parts are activated depending on the action to perform on them.

Most interestingly, these results show that object concepts are represented as patterns of potential actions. This is particularly true for artifact concepts. In fact, the interaction between concept kinds and congruency between parts and actions shows

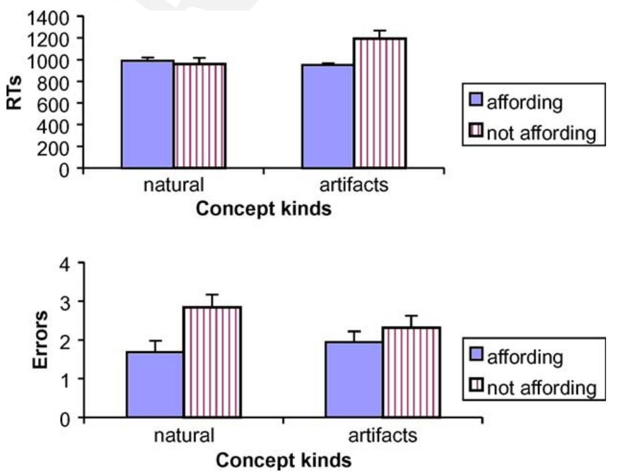

Fig. 2. Experiment 3. Differences in RTs and accuracy between affording and non-affording parts.

that in artifact concepts non-affording parts are processed slower than affording ones. Overall, the results reflect the deep relations between conceptualization, perception and action and support the perceptual symbols view of conceptualization. In fact, as occurs with perception, with conceptualization the action intention also selects relevant perceptual features.

However, an objection could be raised which invalidates the last point: given that the association degree between the verbs and the parts was not controlled, the results obtained do not completely rule out an account of concepts based on associations in a semantic network. In fact, the advantage of the pairs where there was congruency between action and part over those with no congruency may simply depend on the association degree between the verb and the object part (e.g., 'divide' could be more associated to 'slice' than to 'pulp'), not on their being affordances for actions. The aim of Experiments 4 and 5 is to rule out this hypothesis by providing convergent evidence obtained with different tasks.

6. Experiment 4

The aim of Experiment 4 was to verify, using the same procedure, that the results of Experiment 3 were not simply due to word association but that they were the result of a meshing process between the action to accomplish and the objects' parts. A new list of trials was construed: the material was controlled so that in each sentence the verb was not more semantically associated to the affording than to the non-affording part.

6.1. Method

6.1.1. Participants

Twenty-eight students of the University of Bologna volunteered their participation. Both affordance (affording vs. non-affording parts) and concept kind (artifact vs. natural kind) were manipulated within participants.

6.1.2. Material

The material consisted of 22 sentences, 11 of which had a natural kind concept as object and 11 of which had an artifact concept as object, followed either by a part which could be a good affordance for the expressed action or by a non-affording part, for a total of 44 trials. An example: 'The child distributed the orange—slice' (natural kind, affording part); 'The child distributed the orange—pulp' (natural kind, non-affording part); 'The boy lifted the wardrobe—legs' (artifact, affording part); 'The boy lifted the wardrobe—shutter' (artifact, non-affording part). The material was selected after two pre-tests. In the first, 20 participants were asked to produce 20 associates to the verb. None of the participants associated the critical parts to the verb. In the second pre-test, 20 participants were required to produce five associates to the whole sentence. Only a few associated parts were produced, and there was no difference in frequency and production order between affording and non-affording parts. Part familiarity and length were controlled: there was no difference in familiarity of affording vs. non-affording parts ($p < 0.188$) and the number of syllables of the parts was the same across the different conditions.

Forty-four fillers were added to the 44 trials in which the part following the sentence was not a part of the sentence's object (e.g., 'The child distributed the orange—nail').

6.1.3. Procedure

The procedure was the same as in Experiment 3: participants had to press a button in order to decide whether or not the part noun following a sentence referred to a part of the sentence's object. They had to press the 'yes' button with their dominant hand. The trials were presented in a different random order for each participant. Sixteen practice trials preceded the experiment. Unlike Experiment 3, in this case participants were instructed to read the whole sentence preceding the part as they could be tested on it later. This slight modification was introduced in order to rule out the possibility that participants paid attention only to the object of the sentence and not to the whole sentence.

6.2. Results

The results of one participant were discarded because he/she had very slow RTs on some trials, indicating that he/she did not perform the task attentively enough. RTs were removed for target trials in which errors occurred. RTs higher or lower than the average ±2 standard deviations for each participant for each condition were eliminated. In this way less than 2% of the data was eliminated. Overall, RTs in this experiment are longer than those in Experiment 3. This might have to do with the change in instruction, because participants in this experiment were invited to pay attention to the whole sentence as they could be tested on it later.

In the ANOVA performed on RTs there was a main effect of affordances: as expected affording parts had shorter latencies than non-affording parts ($M = 1134$ vs. $M = 1201$) ($F(1,26) = 5.58$, $MSe = 21\,489.41$, $p < 0.02$) with both artifacts and natural kind concepts. In the accuracy analysis there was no effect of affordances, but the error means had the same trend as the latency means, showing that no speed-accuracy tradeoff occurred. A main effect of concept kinds ($F(1,26) = 11.84$, $MSe = 11.84$, $p < 0.01$) showed that natural kind concepts elicited more errors than artifacts ($M = 1.55$ vs. $M = 1.07$). Also, the interaction was significant ($F(1,26) = 11.46$, $MSe = 0.83$, $p < 01$), due to the fact that artifact concepts elicited much fewer errors with affording parts than with non-affording parts ($p < 0.01$) and with both affording ($p < 0.01$) and non-affording parts of natural kind concepts ($p < 0.01$), as shown by post hoc Newman–Keuls (see Fig. 3).

6.3. Discussion

The results confirm and strengthen those obtained in Experiment 3. As predicted, latencies were shorter with affording than with non-affording parts. This indicates

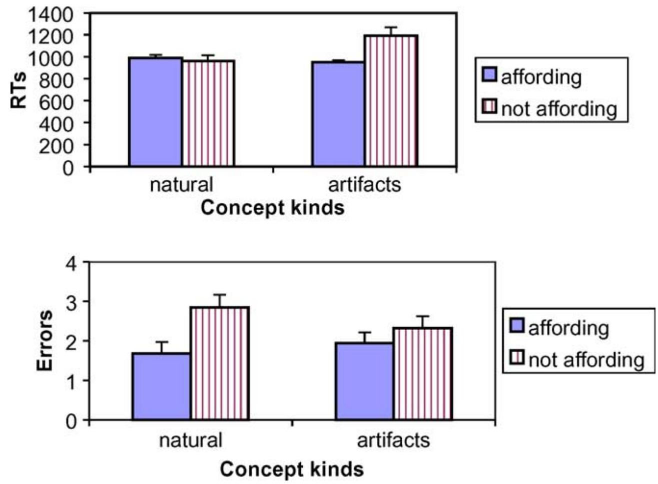

Fig. 3. Experiment 4. Differences in RTs and accuracy between affording and non-affording parts.

that not all affordances are automatically activated, but rather that only the affordances that are activated by the sentence and relevant for its comprehension are activated automatically (Kaschak & Glenberg, 2000; Stanfield & Zwaan, 2001). In addition, the results indicate that objects are not holistically represented but that different objects' parts can be affordances depending on the kind of action.

The accuracy analysis confirms what was found in Experiment 3: artifacts' parts are stronger affordances than natural kinds' parts. This result is congruent with literature on the neural basis of cognition showing that while artifacts are processed the sensory-motor cortex is activated.

7. Experiment 5

The aim of Experiment 5 is to confirm the results of Experiment 4 with a different paradigm, i.e., to demonstrate that the results of Experiment 3 are not simply due to word association but to the sentences expressing actions which selected affording parts. The same material of Experiment 4 was used. The task consisted in rating on a seven-point scale how much a given part made sense in combination with the sentence.

The paradigm used strongly resembles the one used by Glenberg and Robertson (2000) who found that participants evaluated as more sensible sentences like 'After wading barefoot in the lake, Erik used his shirt to dry his feet' than sentences like 'After wading barefoot in the lake, Erik used his glasses to dry his feet'. The results can be explained by the fact that shirts, due to their perceptual features, afford the action of drying feet, whereas glasses do not.

7.1. Method

7.1.1. Participants

Twenty-one students of the University of Bologna volunteered for the experiment. Both affordance (affording vs. non-affording parts) and concept kind (artifact vs. natural kind) were manipulated within participants.

7.1.2. Material

The same material of Experiment 4 was used.

7.1.3. Procedure

Participants were presented with all the randomized trials and were asked to rate, using a seven-point scale, "How is the part following the sentence plausible in the context of the sentence?"

7.2. Results

Affording parts ($M = 4.97$) were rated as more plausible in the sentence's context than non-affording parts ($M = 3.47$) ($F(1,20) = 49.61$, $MSe = 0.95$, $p < 0.01$), despite the fact that the sentences and the parts were not associated (see Fig. 4).

7.3. Discussion

The results confirm and extend those obtained in Experiment 3.

First, they show the advantage of affording over non-affording parts with a different task, consisting of plausibility judgements. The difference between the affording and non-affording parts is not due to associations in a semantic network, given that both affording and non-affording parts are low associates of the preceding verb. It could be objected that this result is obvious, given that the parts used are certainly selected to be more plausible in a given context, and the ratings obtained are simply a consequence of the way the material was selected. Consider, however, the implications of this result. Both kinds of sentences, those with affording and those with non-affording parts, are syntactically correct, and both are perfectly meaningful. Most importantly, the association degree between the verb of the sentence and the parts mentioned in the two sentences does not differ. This suggests that people make plau-

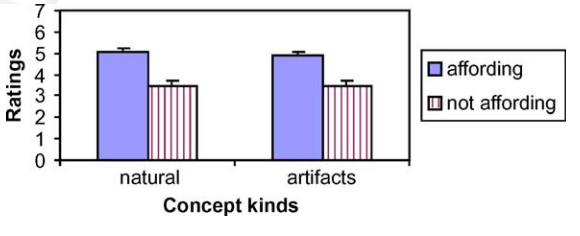

Fig. 4. Experiment 5. Differences in average sensibility-ratings between affording and non-affording parts.

sibility judgements by envisioning the perceptual characteristics of parts, extracting their affordances, and meshing them with the action expressed by the sentence (Glenberg & Robertson, 2000). This process makes it possible to quickly understand the sentence's meaning. Indicating that parts with certain physical characteristics afford actions, the results suggest that objects and their parts are represented through perceptual symbols grounded in actions and not through arbitrary symbols. There is, however, a way in which amodal theories could explain such a result. It could be argued that, while reading and evaluating sentences, one could come up with some line of reasoning to arrive at the interpretation that one part is more plausible than another in a given context. This is a plausible explanation. However, it is certainly less economical than the first—one should extract all the properties of a part and verify whether they match with the meaning conveyed by a given sentence. Further, this explanation would not fully clarify why participants evaluated a particular combination as making sense quickly and easily.

A final point is worth noticing. The absence of a difference between artifacts and natural kinds opens the possibility that, for both kinds of concepts, parts afford actions, i.e., that both artifacts and natural kinds can be conceived of as action-based concepts.

8. General discussion

The results have a number of theoretical implications.

First, they indicate that parts relevant for actions are activated more than other parts across situations; this suggests that objects are conceived of in terms of the potential actions we may perform with them (hypothesis 2a). The fact that default affordances are dictated by their importance for more frequent actions (Palmer, Rosch, & Chase, 1981) is very plausible from an evolutionary point of view. There is much evidence converging on the importance of default affordances: it is sufficient to think of the well known literature on functional-fixedness (Duncker, 1926), as well as of the more recent literature in cognitive ergonomics (Norman, 1988).

However, this is not the whole story. This research also shows that our cognitive system subserves action in a more subtle and sophisticated way, by storing information which might be relevant for future actions in different situations. In fact, the existence of default affordances does not exclude the variability of conceptual organization; the results also indicate that, depending on the different kind of interaction with objects, different parts are affordances (hypothesis 2b). As in perception, in conceptualization the action intention also selects perceptual features apt for acting. Experiment 1 provides evidence supporting the view that different concept parts are activated depending on the simulated kind of interaction we have with objects: different parts are activated and with a different production order when we simulate to build objects or to visually interact with them. Experiment 3 shows, with a part verification task, that with the same object the parts activated (affordances) depend on the kind of activated action. So, different parts of the same object may become affordances for different actions: for example a knife's blade can be a good affordance for the action of cutting whereas its handle can be a good affordance for the action of grasping. The results are consistent with previous evidence showing that, depending on the situation, different object characteristics are activated (Barsalou, 1982). Borghi and Barsalou (2001) showed with a feature generation task that, when participants imagine seeing a telephone, they produce mainly visual properties (e.g., grey), when they imagine throwing it mainly tactile properties (e.g., smooth), and when they imagine hearing it, they produce mainly auditive properties (e.g., rings) (see also Klatzky, Pellegrino, McCloskey, & Doherty, 1989; Klatzky, Pellegrino, McCloskey, & Leberman, 1993; Pecher et al., 2003).

Experiments 4 and 5 were devised in order to prevent a possible objection. In fact, the results of Experiments 1–3 demonstrate that conceptual organization is variable and that action is a powerful mechanism for preserving object information (for convergent neuropsychological evidence see Magniè, Ferreira, Giuliano, & Poncet, 1996), but not necessarily that concepts are embodied. In fact, they could be explained by a semantic network account stating that, for example, the semantic association between 'cut' and 'blade' is stronger than the semantic association between 'cut' and 'handle'. The aim of Experiments 4 and 5 was to show with both a part verification and a sensibility-rating task that this was not the case. The results clearly indicate that the effects found depend on objects' parts affording actions, i.e., on the specific match between object properties and action, and that the results cannot be explained by an account based on semantic associations. For example, the petals and the corolla of a flower are not semantically associated to the action of stripping, but the perceptual properties of petals, their length and consistency, afford stripping much more than the perceptual properties of the corolla. Overall, the results suggest that objects are represented through symbols that are perceptual, and not arbitrary.

The finding that objects are conceived as patterns of potential actions is predicted by embodied and situated theories of concepts. Consider how an embodied theory of concepts can explain the results: a sentence, such as for example 'Imagine building a car' in Experiment 1 or 'The woman shares the orange' in Experiments 3–5, guides a certain simulation. This simulation leads to a selective activation of parts of the perceptual symbol, the car or the orange, whose perceptual characteristics are compatible with the action described in the sentence. Thus in Experiment 1 participants produce different parts depending on the simulation, and in Experiments 3–5 affording parts are accessed earlier, and evaluated as making more sense within the sentence, than non-affording parts. In Experiment 2 it is not the sentence that guides the simulation, but the object name. Simulating a car leads participants primarily to access parts of the car that are relevant for canonical actions with it. This explanation is economical, natural and simple.

Even though the results are more easily predicted by an embodied account, in principle they could be also accounted for through amodal views of knowledge representation that allow for interactions between the concept core and a sort of perceptual-motor memory. Successful amodal views postulate the existence of two levels in knowledge representation: a purely symbolic layer and a procedural layer that, operating on the symbols, "instructs" the symbolic layer on how to operate in the world. Let us consider the way in which an amodal account could interpret the results of the different experiments. The proponents of the amodal view might argue that the results of Experiments 1 and 2, obtained through a part-generation task, reflect the association degree between a given perspective sentence and the produced parts. This explanation is weakened if one considers the fact that the experiments provide evidence of both canonical and situational effects, and not just of situational effects. However, an amodal account could also explain canonical effects: for example, by arguing that the symbols representing a car may have a stronger connection to symbols representing the steering wheel, the brake and the seats, than to symbols representing the roof and the antenna. Now consider Experiment 3. The results could be due to the higher semantic relatedness between a sentence and the object's affording parts than between a sentence and the object's non-affording parts. However, the results of Experiments 4 and 5, which do not depend on semantic relatedness, rule out this interpretation. In this case too, however, an amodal account could postulate the existence of some procedures for using the description to guide comprehension, and, eventually, action (e.g., when sharing an orange, focus on its slices; when eating it, focus on its pulp).

Thus, an amodal account could explain the results found, even though it would be difficult to predict them from an amodal point of view. Amodal accounts are very powerful, and in principle they can explain everything. However, the results found are more naturally and easily predicted by an embodied theory of knowledge, and an explanation based on an amodal account would have some shortcomings. The first shortcoming is that of symbol grounding: how do amodal accounts deal with the relationships between symbols and perception and action experience (Harnad, 1990)? This leads to the second shortcoming: they can explain the results of the experiments post hoc, but there is no principled way in which they could predict them. The third shortcoming is that, in providing an explanation, they need to postulate an enormous set of symbols, procedures, inter-connections between symbols. For example, they should postulate that the action of ripping a flower activates certain parts, such as petals, stems and others, whereas the action of offering it activates different parts. However, in order to explain the flexibility of human knowledge, the number of symbols, links, and procedures, may become increasingly wide and create a problem of combinatorial explosion (for a more detailed discussion of this point see Borghi, Glenberg, & Kaschak, submitted for publication). So, the results suggest that concepts are represented as pattern of potential actions, and that a currently activated action increases the psychological salience of affording parts. Even though a propositional account of concepts that allow for interaction with motor memory could also account for these results, an explanation of the results based on a sensory-motor account of conceptualization seems more parsimonious, elegant and plausible.

A further point is worthy of discussion. Consider the fact that parts are generally considered as perceptual rather than functional features. The results also show that perceptual features, like parts, are differently activated depending on their power in affording actions (Tucker & Ellis, 1998). This argues for a strong interaction between perception, action (Bekkering & Neggers, 2002; Jeannerod et al., 1995; Knoblich & Flach, 2001) and conceptualization. Recent evidence in this direction has been provided by Glenberg and Kaschak (2002), who show that, when a sentence implied an action in a direction, participants had difficulties making a sensibility judgement requiring them to press a button moving in the opposite direction. In the same vein, Borghi et al. (submitted for publication) recently found a congruency effect between the location of a part noun, upper or lower (e.g., cork vs. bottom of a bottle), and the upper or lower location of a key to press in performing a part verification task. In the same line, Carlson (2000) has demonstrated the importance of functional information for spatial relations as 'above', as function significantly influences the selection of reference frames. Probably for adaptive reasons, the way we store and retain information on objects and on object parts in memory is deeply influenced by the potential actions we can perform with them (Wilson, 2002).

In addition, the results found imply that objects are represented componentially rather than holistically. Most interestingly, they suggest that, at least for the considered items, object compositionality is grounded in action: in fact, object parts are separately activated as they may afford different actions.

A last point is worthy of discussion. In the last three experiments contradictory results are found with respect to the role affordances play for artifacts and natural kind concepts. In Experiment 5, which consisted in a slow rating task, the difference between concept kinds was not significant. In Experiments 3 artifacts' non-affording parts were processed slower than artifacts' affording parts and than natural kinds parts, in Experiment 4 artifacts' affording parts elicited less errors than artifacts' non-affording parts and than natural kinds parts. Evidence convergent with the advantage of artifacts' affording parts is provided by studies showing that artifacts mainly elicit functional and action features. This evidence could also be accounted for by a domain-specific view of knowledge organization, according to which evolutionary pressures have resulted in specialized neural circuits dedicated to processing different categories. As argued by Mahon and Caramazza (in press), the plausible candidates for this are the categories that are relevant for our evolutionary history such as animals, plants, con-specifics, tools.

However, the results suggest that the difference between artifacts and natural kinds could be simply a matter of grade, due to the fact that artifacts are more often acted with in the same way, while natural kinds are not (Parisi, personal communication). For example, we generally use chairs for sitting, while we generally interact with cats in many different ways—petting them, feeding them, playing with them—so that several parts may become salient. Thus, the results open the interesting possibility that all concepts, and not only artifacts, are conceived as possible action patterns.

Another possibility is partially compatible with the results found. It is possible that the absence of a clear difference between artifacts and natural kinds is due to the fact that both the artifacts and the natural kind concepts used were manipulable and are generally acted with. In this line, recent papers suggest that the difference between artifacts and natural kinds should be reformulated in terms of the difference between manipulable artifacts and natural kinds such as watches and oranges, and non-manipulable artifacts and natural kinds such as statues and stars (Gerlach, Law, & Paulson, 2002).

Acknowledgements

I would like to thank the students of a seminar in cognitive processes (in alphabetical order) who participated in the preparation of the material, data collection, and the ideation of experiment 3: Federica Calanchi, Diego Cofone, Maurizio Giudice, Francesco Migliorini, Edoardo Osculati, Andrea Rubbini. Thanks to Ann Gagliardi for help with English. I would also like to thank Art Glenberg for useful suggestions during planning of the last experiments and for discussion of these themes and to Morana Alac, Tina Iachini, Mike Kaschak, Domenico Parisi, Diane Pecher, René Zeelenberg, Rolf Zwaan for comments on a previous draft of this paper. Thanks to Jan Vanrie, Johan Wagemans and an anonymous reviewer for useful comments and suggestions. Special thanks to Larry Barsalou for inspiration as well as for comments on a previous draft of this work. This research was financed by a Giovani Ricercatori 2001–2002 grant awarded by the University of Bologna to the author. This research was presented at the First Annual Summer Interdisciplinary Conference, Squamish, BC, Canada, July 30–August 4, 2002.

Appendix A

A.1. Experiments 1 and 2—materials

1. Bicycle
2. Washing machine
3. Car
4. Piano
5. Motorbike
6. Mixer
7. Hi-fi

A.2. Experiment 3—materials

1. The child divided the orange/tasted the orange—slice/pulp.
2. The woman ate the watermelon/threw the watermelon away—seed/skin.
3. The man cut the grapes off/savored the grapes (uva)—stalk/grape (* in Italian it's a different word: acino).
4. The girl pet the cat/bothered the cat—head/tail.
5. The girl fed the bird/picked up the bird—beak/wing.
6. The girl rode the pony/fed the pony—back/muzzle.
7. The man sawed the tree/paused under the tree—trunk/leafy branch.
8. The boy cut the flower/gave the flower as a present—stem/corolla.
9. The boy picked up the rose/smelled the rose—thorn/petal.
10. The man chewed the fish/caught the fish—bone/mouth (of the fish).

11. The woman cleaned the artichoke/enjoyed/savored the artichoke—leaves/hearth.
12. The man pruned the olive tree/planted * (cut off) the olive tree—branch/root.
13. The man grasped the knife/cut with the knife—handle/blade.
14. The boy untied the shirt/folded the shirt—button/arm.
15. The girl read the book/found the book—page/cover.
16. The woman opened the bottle/raised the bottle—cork/bottom.
17. The woman put the skirt on/ironed the skirt—zip/fold.
18. The child leaned against the chair/turned the chair over—back/legs.
19. The girl closed the door/slammed the door—handle/shutter.
20. The man loaded the car/drove the car—trunk/steering wheel.
21. The boy lay down on the bed/sat on the bed—mattress/headboard.
22. The girl controlled the watch/took the watch off—(watch) strap/(watch) hand (* in Italian both words are specific for watches: cinturino, lancetta).
23. The man played the piano/transported the piano—key/tail.
24. The boy set the table/lifted the table—shelf (of the table)—feet.

A.3. Experiments 4 and 5—materials

1. The woman shares/distributes the orange—slice—pulp.
2. The boy takes the cat—stomach—eye.
3. The girl throws the watermelon away—skin—seed.
4. The boy devours the artichoke—hearth—leaves.
5. The girl rips/tears the flower—petal—corolla.
6. The boy picks up the bird—legs—beak.
7. The girl hugs/embraces the tree—branch—leaves.
8. The man caught the fish—mouth—bone.
9. The girl keeps the butterfly—wings—head.
10. The woman mounts the bear—back—muzzle.
11. The boy feeds the dog—tongue—tail.
12. The girl puts the watch down—watch strap—watch hand.
13. The boy extracts the book—cover—page.
14. The man gets off the motorbike—pedal—light.
15. The woman smoothes the shirt—arm—knob.
16. The girl puts the bottle down—neck—cork.
17. The woman dyes the jacket—pocket—zip.
18. The man enters the car—seat—trunk.
19. The man paints the door—hinge—lock.
20. The boy lifts the wardrobe—legs—shutter.
21. The woman raises the glasses—legs (*in Italian it is a word specific for glasses)—lens.
22. The man cleans the computer—screen—key.

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